

ENGINEERING

FACTS AND FIGURES

—
1866.

Nath. A. 50^h₋

Brown

NOTICES BY THE PRESS

ON VOLUMES FOR 1863 TO 1865.

1863.

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ENGINEERING
FACTS AND FIGURES FOR 1866.

AN

ANNUAL REGISTER

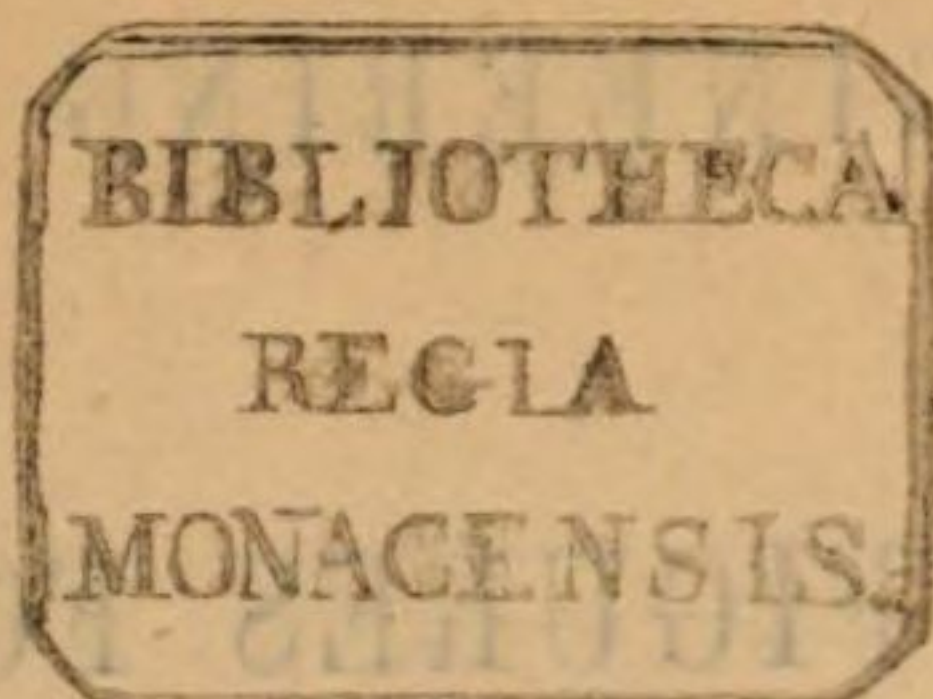
OF PROGRESS IN

MECHANICAL ENGINEERING AND CONSTRUCTION.

Brown

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1867.



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P R E F A C E .

IN presenting this the fourth volume of Engineering Facts and Figures, the Publishers have the satisfaction to state that its usefulness to the important class for whom it is designed still continues to be testified to, by a large number of influential authorities. By improvements in the arrangement of the various Divisions of the work, by which its varied and valuable contents can be readily referred to, and by giving in addition a list of important papers for the insertion of which space could not be had, they hope to make the present volume still more worthy of acceptance.

In preparing this volume, the Editor has to acknowledge his obligations for the chief mass of the matter contained in it to the following periodicals:—‘The Engineer;’ ‘Engineering;’ ‘The Mechanics’ Magazine;’ ‘The Building News;’ ‘The Builder;’ ‘The English Mechanic;’ ‘The Practical Mechanics’ Journal;’ ‘The Civil Engineer and Architect’s Journal;’ ‘The Scientific Review;’ ‘The Journal of the Society of Arts;’ ‘Newton’s London Journal of Arts;’ and the ‘Scientific American.’

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ENGINEERING

FACTS AND FIGURES FOR 1866.

DIVISION FIRST.

BOILERS AND VESSELS FOR CONTAINING STEAM AND OTHER FLUIDS UNDER PRESSURE.

1. THOSE engaged in the designing and constructing of Steam-engine Boilers cannot have the dicta too frequently before them, or cannot too rigidly endeavour to carry out the truths which they involve, and which may be stated as follows :—"The strength of a machine or of an appliance lies in its weakest part," and "the danger of a high pressure fluid, as steam acting upon a vessel in which it is confined, does not consist in the intensity of pressure to which the steam may be raised, but in the character and construction of the vessel." That during the last year—the mechanical features of which it is our duty in the present volume to record—these highly important principles have been most unfortunately overlooked, is patent enough when we draw to recollection the disasters to life and property which, during its progress, have resulted from steam-boiler explosions. In view indeed of the reckless manner in which boilers are designed and constructed and sent into the market, and of the losses which arise from their failure, it is almost impossible to come to any other conclusion than that come to and ably advocated by more than one of our eminent Engineers,—that legislative supervision should be extended to this department of mechanical appliances. If legislative interference is justified in the case of factory ma-

chinery, the arrangement and working of mines, or in the inspection of steam ships, it surely can be justified in the case of steam boilers. It would seem to be of little use to argue on the basis that individual interest will secure individual care ; for however absurd it seems, it is nevertheless true that the most reckless indifference to the interests of life and property alike prevails to a most alarming extent amongst the makers and users of steam boilers. Whatever may be the opinion, however, of some as to the wisdom, or otherwise, of controlling individual action by legislative enactments, of this there can be no manner of doubt, that a heavy responsibility rests with those who design and construct these appliances, and send them out to customers as sound and in every way effective. Excuses may be found, and valid ones, for the users of boilers ; there can be none for the makers of them. The users may have this to plead, that they are professionally ignorant of the whole subject ; and that being so, is one of the reasons, if not the only reason, why they call in the aid of those who profess to be otherwise. The result of years of experience, in many respects both painful and expensive experience, points to this—that the morale as well as the professional capacity of many now acting as Engineers must be raised before we can witness any high degree of reform established in this important department of Engineering. Something can be done in this direction—something ought to be done if men take but a proper view of their position and their relationship as advisers to their customers or clients—and something must be done if we wish to see lessened the number of those catastrophes which happen from year to year, and are as little creditable to our humanity as they are to professional capacity and intelligence. Adopting in our *resumé* of what has been recorded in the departments now under consideration, the same arrangement as decided upon in last volume, we now proceed to the first part of our subject—being

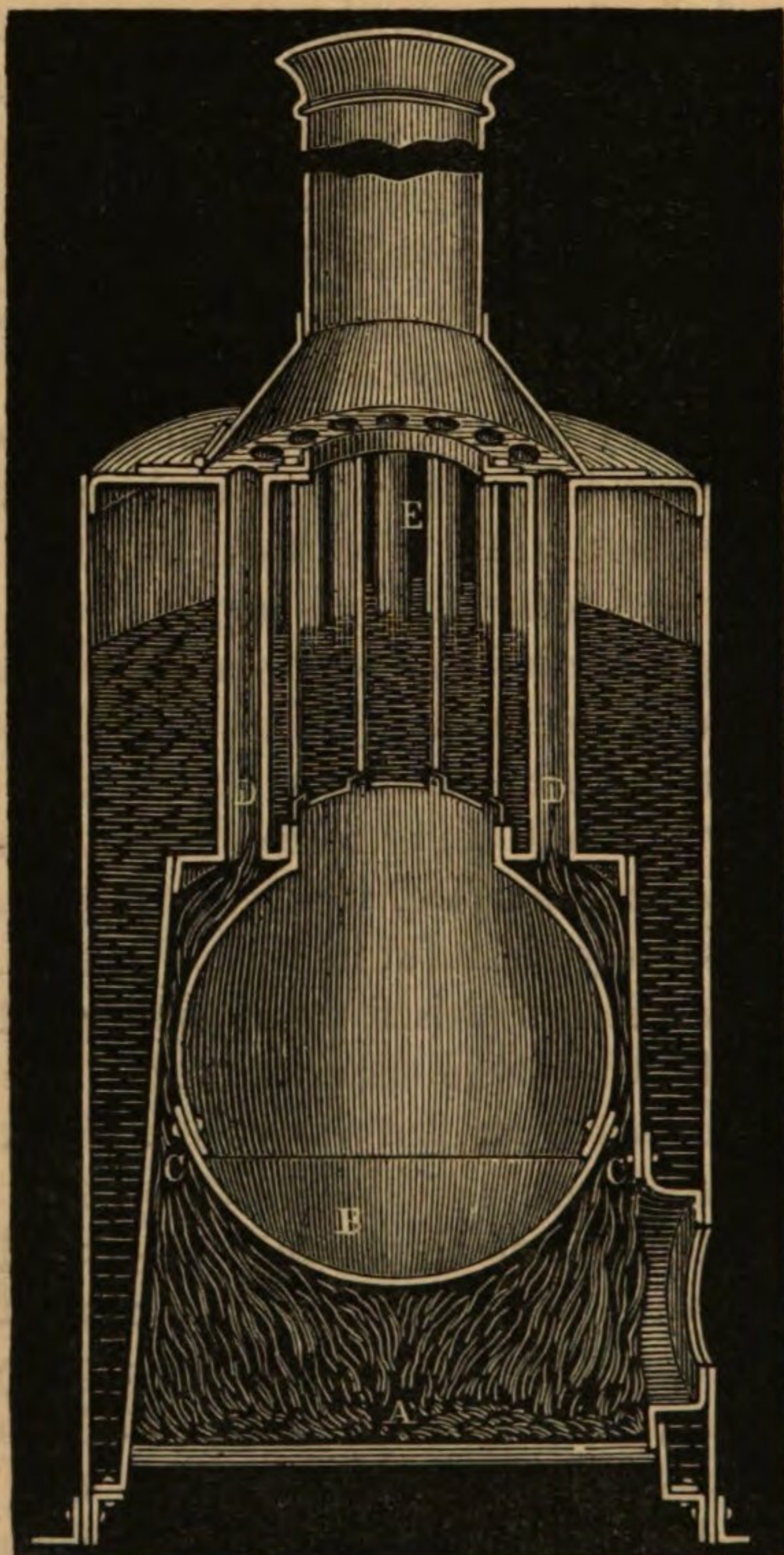
SECTION FIRST.—FORMS, MATERIALS, AND CONSTRUCTION
OF BOILERS.

2. *Thomson's Patent Steam Boiler*.—"For the smaller class of steam boilers," says the *Practical Mechanic's Journal*, "the vertical form has so many recommendations that attempts are

constantly being made to avail of their great economy of space, cheapness of first cost, and other advantages which that kind of boiler offers; but these good points in all the vertical boilers hitherto devised have been accompanied by drawbacks of a very serious kind. It has been found that when the boiler is made with an internal furnace, and a mass of vertical tubes leading from the crown of the furnace to the chimney, two kinds of mischief speedily show themselves. The boiler primes excessively whenever the fire is urged, and the tube-plate burns and cracks after a very short use. The great areas both of fire-grate and heating surface which can be got in this kind of boiler, at a comparatively low cost, constantly tempt inexperienced persons to make them; but there can be no doubt boilers of this sort are, from their great liability to prime, and from their perishable character, utterly condemned by all experienced makers and users of steam boilers. Another kind of vertical boiler in general use is that having a large and lofty internal furnace, with one flue leading to the chimney. From the very small heating surface presented by this form of boiler, and from the comparatively large open channel through which the flame and heated gases rush direct to the chimney without being forced into actual contact with any part of the heating surface, it is very inefficient as a steam producer, and excessively wasteful in fuel. It is, however, fairly durable. A modification of this form of boiler (which, however, is only applicable to the large sizes) consists in placing several large horizontal tubes across the furnace above the fire, which plays on their external surface. These tubes are an improvement, but they still leave much of the flame and heated gases free to rush to the chimney without being forced into contact with any part of the heating surfaces. Cross tubes are both costly to make and troublesome to fit in; they are also liable to accumulate deposits inside, and as it is not possible to clean them out, they speedily burn. Thomson's boiler, of which a vertical section is shown in the accompanying engraving, Fig. 1, combines all the good points of the vertical boilers hitherto in use, and has, in addition, its own special merits. The spherical or cylindrical generator, B, receives the full effect of the flames, which impinge directly on it, sticking on its lower surface with a great rapidity, and then, without losing their velocity, they are deflected against the sides of

the furnace. As they rush past the narrow annular space at c c, the flames and heated gases are necessarily brought into actual contact with the sides of the fire-box and with the surface of the spherical generator. The flames and gases are forced to pass in

Fig. 1.



a thin sheet through this narrow passage, and are thus enabled and compelled to give off to the heating surfaces nearly all the heat they possess. By the time the hot gases have reached the tube-plate they will have parted with so much heat that they will be no longer hot enough to burn it. In the ordinary vertical

boiler the tube-plate is exposed, not only to the direct action of the flames and hot gases, but also to the intense heat *radiating* from the incandescent fuel, and, at the same time, the circulation of the water over the tube-plate is excessively hampered by the tubes standing all over its surface. It soon burns out, as might be readily expected. In this boiler the spherical steam generator, B, is interposed between the fire and the tube-plate. Its shape and position are both specially adapted for receiving and transmitting to the water within the full effect of the fire without, while at the same time it leaves for the tube-plate and tubes only that moderate amount of work which horizontal tube-plates and vertical tubes are capable of doing without being speedily burnt out. The rapid circulation of water over the internal, and the quick rush of flame and hot gases over the heating surfaces of a steam boiler, are alike essential and important for the rapid generation of steam. Any hindrance to the passage of flame and smoke through the flues and tubes of steam boilers is easily detected, and generally not difficult to remedy; but the movements of water in a boiler are less open to inspection, and a sluggish and entangled circulation is no doubt the most frequent cause of the poor performances and short lives of very many steam boilers. The mischievous effect of a coating of soot in a tube is quite well known, and care is taken to remove accumulations of soot and ash from the tubes and flues; but there is no doubt many steam boilers are incapable of doing their full work from the constant existence of an internal coating of steam, which in one sense is more injurious than a coating of soot outside. A layer of either substance, interposed between the fire and the water, will equally prevent the former getting at the latter, but the soot has at least the advantage of protecting the iron from burning, while the coating of steam leaves the iron at the mercy of the fire. The generator, B, presents itself to the action of the fire, under the very best conditions for doing the maximum of work with the least possible injury to itself. The lower part of the sphere is close to the burning fuel, and receives, under the most favourable conditions, both the heat *radiating* from the burning fuel and the direct impact of the flames. Externally, neither soot nor ash can settle on any part of the generator, B, and the water within circulates with a rapidity that clears the internal surface from steam as quickly as

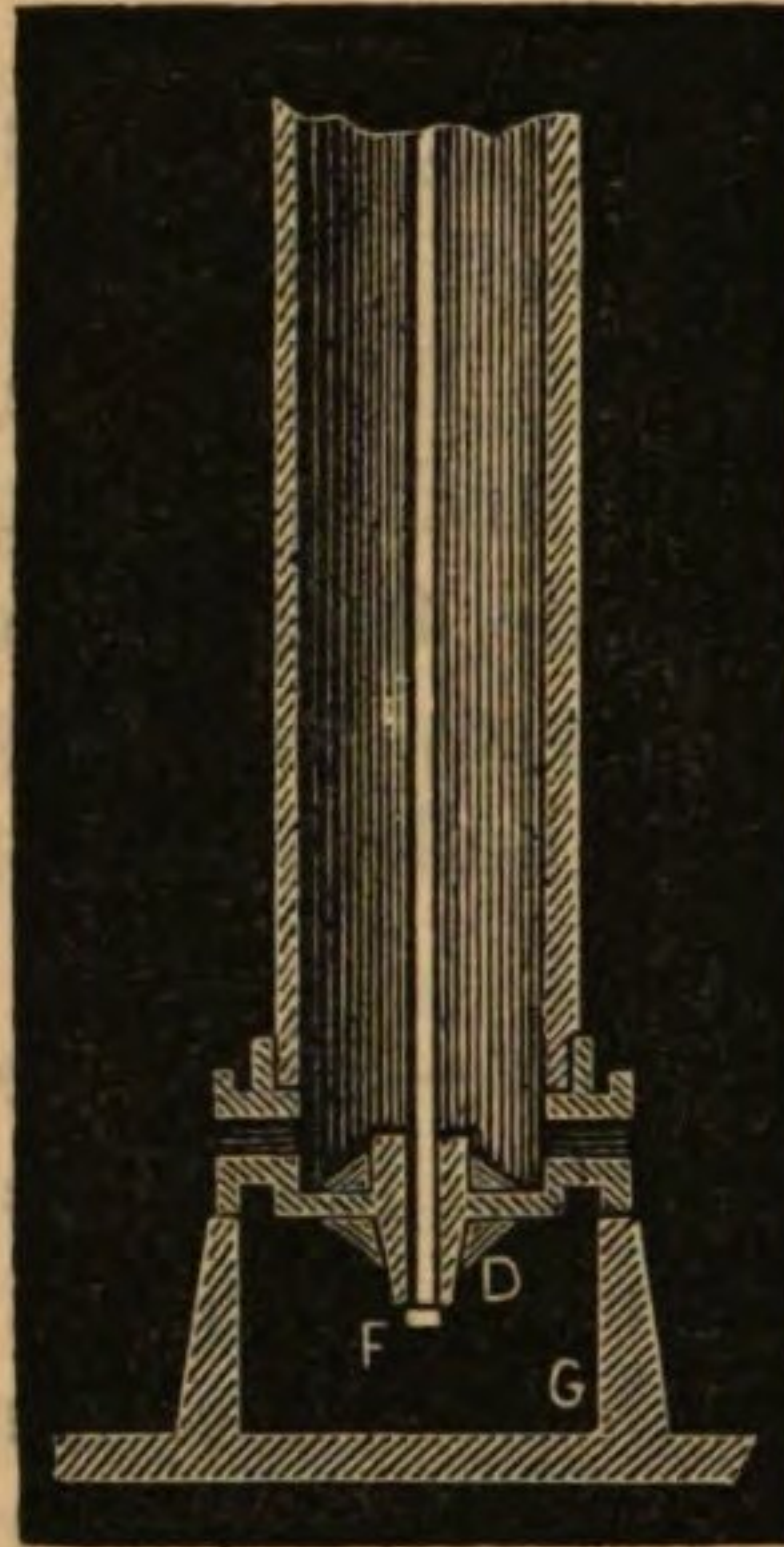
it is generated. The spherical form gives the greatest possible strength, and is entirely free from *stays*, which, in the case of square and flat sided fire-boxes, such as in ordinary locomotives, hamper and hinder to a very great extent the circulation of the water. There can be no question that the lower surface of the sphere, B, receives the full effect of the fuel, both by radiation and by the impact of the flames, in a manner more conducive to the rapid and economical formation of steam than any other shape of fire-box which has as yet been proposed; while, at the same time, it is the strongest possible form. The circulation of the water in the steam generator B, effectually prevents the settlement of mud or any other sediment within it. Every kind of sediment is tossed out of the generator B, and finds a resting-place only in the water space below the level of the fire-bars, from whence it can be removed, from time to time, through mud holes. It is found, from actual trials, that the lower surface of the generator, B, maintains a cleaner surface, internally and externally, than any other part of the boiler, and therefore is not only in the highest degree efficient as a steam generating surface, but is exempt from all risk of burning. The superiority of the surface presented by the lower part of the generator, B, over an equal surface in the crown of the fire-box of a common locomotive boiler, with which it corresponds in position, both being immediately over the fire, is accounted for by the fact, that in the case of Thomson's boiler, the flames and hot gases (which give off their heat to the boiler by *actual contact* with it) impinge with great rapidity all over the lower surface of the generator, B, while in the locomotive boiler they do not strike the crown of the fire-box at all, but immediately on leaving the fire curve off in a horizontal direction into the tubes. The crown of a locomotive fire-box, doubtless, forms a great deal of steam, but it depends for its efficiency, mainly on the heat *radiating* from the incandescent fuel. In Thomson's patent boiler the lower part of the generator, B, has the benefit of the heat radiating from the burning fuel in even a higher degree than in the locomotive boiler, because it lies much closer to the fire, and the generator has the still more beneficial action of the fire *blowing* on it, a source of efficiency entirely wanting in the locomotive boiler. Unless this difference is kept in view, it would be quite impossible to

account for the superior performances of Thomson's boiler, when compared with the locomotive boilers having the same amount of heating surface. The opening of the man-hole, at E, exposes to view the whole interior of the tubes, tube plates, and central generator. They can all be seen, cleaned, and repaired without any difficulty, and without pulling any part of the boiler to pieces. The great importance of this facility will be fully realized by those who use water containing mud, lime, or salt. For working ships' winches, evaporating salt water for the use of the crew and passengers, the new boiler possesses several advantages. It has all the good points of tubular boilers without any of their disadvantages. It has the simplicity, durability, and facility for cleaning out and repairing of bulky boilers without tubes, while, at the same time, it occupies less room, and raises more steam than the very best tubular boilers (having the same surface), whether those boilers are vertical or of the ordinary locomotive shape."

3. Of a new form of boiler—which goes by the name of the "Combination Boiler"—"The Mechanic's Magazine" has a description from which we have arranged the following:—"One of the most important conditions necessary to ensure the perfect and economical working of boilers is thorough circulation of the water. Among the most recent methods of effecting this may be noticed the invention of Mr. T. B. Jordan, of Milton Cottage, South Lambeth. This is a peculiar arrangement of metal cylinders open at both ends. These cylinders are fitted into connecting rings or collars, which are also open at the ends, and have steam and waterways cast through their opposite sides. Each of these cylinders is of sufficient size for a boiler of one-horse power. The ends of the cylinders are closed by cast-iron covers, which are held in place by staybolts passing through the centre of each cylinder, and through the top and bottom covers, so as to tie the covers together and make a good steamtight joint against the ends of the connecting rings. These joints are made tight by any of the usual means of making manhole or other steam joints, but Mr. Jordan prefers turning the metal surfaces in the lathe, so that the joint may be made perfect with great facility by using a very small quantity of putty or mastic, to admit of their being broken and remade as often as may be found requisite for cleaning the boiler.

"Fig. 2 is a vertical section of one of the cylinders detached. Brickwork, which encloses the furnace and the space in which the metal cylinders are arranged open at both ends. Metal rings or collars are fitted to each end of the cylinders. These collars are open at the top and bottom, and are cast with openings at opposite sides for the passage of water, or of steam, as the case

Fig. 2.



may be. These openings are flanged so as to admit of a series of the cylinders being connected together as shown. D D are cast-iron covers, which are fitted to the collars so as to close the upper and lower ends of the cylinders, and are held in place by staybolts E E, which pass through the top and bottom covers, and are secured by nuts. The cylinders are arranged vertically in rows between the walls of the furnace; the flanges of the lower rings C rest on projecting ribs of a cast-iron bed-plate G. Spaces are left between the ribs of the bed-plate below each cylinder, so as to admit of the lower covers of the cylinders being removed on opening a door at the back of the furnace, and in this way the interior of each cylinder may be cleaned and thoroughly examined. The cylinders which are contiguous to each other are connected by the flanges of the rings or collars, the end cylinders in each row being connected one with the other by coupling pieces and elbow pipes, so that the water passages and also the steam passages of the whole series are in communication

throughout. Stop plates are arranged in the furnace, which serve to conduct the flame and heated gaseous matters round the cylinders, and which, by checking the escape of the gases, cause them to mix intimately, so that their complete combustion is effected. The number of these stop plates may be varied, according to the size and power of the boiler, larger boilers not requiring so many on account of the greater breadth of flue between the enclosing walls. In adapting these cylinders or steam generators to locomotive engines they are enclosed in a water case, which thus forms a portion of the boiler, and they are connected thereto by the flanges of the rings or collars C C."

The same Journal has a description of Captain Hall's "Vertical Tube Boiler," which we here append:—"Economy in obtaining steam combined with rapidity in raising it are the two main objects of most improvements in steam boilers in the present day. Having these points in view Captain Hall, R.N., of Sheerness, has just patented an invention which consists in constructing steam boilers with vertical tubes passing through the furnaces. The portion of the tubes between the top of the furnaces and the water line is conical, the broader diameter being uppermost, while the portion which passes through the furnaces is of uniform diameter and oval. The boiler is constructed with vertical tubes, which pass through the furnaces; the portion of these tubes from the top of the furnace and the water line is conical, the broader diameter being uppermost, and the portion of the tubes (G G) which passes through the furnaces is of uniform diameter, and may be of circular, oval, or other desired shape in section. The tubes (G G) are secured at the bottom to the bottom of the inner casings by means of flanged rings, and at the top to the top of the inner casings by similar rings. They are protected from the direct action of the fire by firebricks. Forked stays are placed between the top of the outer casing A and the top of the inner casings; K K are horizontal stays fitted at various parts as required. The water has free circulation between the outer casing and the inner casings or fire-boxes; also between the fire-boxes and through the tubes (G G). The flame and products of combustion surround the conical portions of the tubes (G G) and then pass through the flue into the uptake. Boilers constructed according to this invention occupy much less

space than ordinary multitubular boilers, and the advantage is thus derived of being able to fit say eight boilers on board a vessel in the space occupied by four ordinary boilers."

4. *Boilers for the Supply of Steam to the Engines in the English Department of the Great Exhibition in Paris in 1867.*—Of these we take the following description from *Engineering*:—"The boilers are each nominally of 45 horse power, but they are calculated to furnish a sufficient supply of steam for engines developing four times that amount of indicated power, it being supposed, of course, that the engines supplied are of good design, and are in good working order.

"The boilers are each 24 ft. long by 6 ft. 6 in. in diameter, and the shells are made of the best Shropshire plates, the barrel plates being $\frac{3}{8}$ in. thick, double rivetted at the longitudinal and single rivetted at the transverse seams, and the joints are crossed half the length of each plate. The end plates are $\frac{7}{16}$ in. thick, and are each in one piece. Each end plate is stayed by means of gusset plates attached to the barrel and ends by double angle irons, and care is taken that a space of 9 in. is left between the gusset stays and the flues, so that sufficient freedom may be given to the end plates around the flues to allow them to adjust themselves to the unequal expansion of the flues and shell. Each boiler contains two furnaces, each 2 ft. 8 in. in diameter by 6 ft. 6 in. long, these furnaces uniting in a back flue of elliptical section, 5 ft. wide by 2 ft. 9 in. high. The furnaces and flues are made of the same description and thickness of plates as the barrel, and the plates forming the furnaces are welded up. The firebars are arranged in the furnaces in three lengths, each 1 ft. 10 in. long. The bars are $\frac{5}{8}$ in. thick, and are set with $\frac{3}{8}$ in. air spaces.

"The chief peculiarity of the boilers consists in the patent water tubes with which the back flue of each is fitted. Each flue is furnished with twenty-one of these tubes and also with four "side pockets," the latter being intended to prevent the flame from running directly through the flue. They are placed at the sides where no tubes are introduced, so as to throw the flame into the centre of the flue, and bring it as much as possible in contact with the tubes. The two pockets nearest the front of the boiler are placed opposite each other, so as to throw the

products of combustion from the two furnaces into immediate contact ; and by alternate firing and the admission of a proper quantity of air through a perforated plate at the bridge, the formation of smoke is very effectively prevented. This system has been adopted by Messrs. Galloway in a number of instances, and has been found by them to answer well. The tubes and side pockets are each made of a single plate without any rivets.

“ From the inside flue of each boiler the products of combustion are led first down each side and then along under the bottom of the boiler. The side flues are 4 ft. 3 in. high, the tops being level with those of the inside flues, and their outside walls are 5 in. clear of the boiler in the narrowest part. The bottom flue is 3 ft. 3 in. wide and 2 feet deep under the centre of the boiler. The boilers are bedded on blocks of fireclay, and the shape and position of these, as well as of the flues themselves, will be seen by the longitudinal and transverse sections. Each boiler is furnished with a steam chamber 2 ft. in diameter by about 6 ft. long, and from the top of these steam chambers, which are each connected to its respective boiler by two pipes, the steam is taken to the engines. There are two safety valves on each boiler, these valves being 4 in. in diameter, and being made with flat faces $\frac{3}{16}$ in. wide. They have no spindle, and have nothing about them that is likely to stick or become fast through corrosion. The feed valve of each boiler is made with the valve itself loose on the spindle, so that it can act as a check valve ; and the blow-off cock, which is fitted to the front end of the boiler, is a disc valve with four openings. The other fittings are of the ordinary construction. The boilers are intended to work at a pressure of 50 lb. per square inch, and will be tested to a pressure of 120 lb. per square inch.

“ The boilers which we have above described are of the class ordinarily constructed by Messrs. Galloway and Sons, who have long advocated the double rivetting of the longitudinal seams, as they argue that the extra expense of such seams does not greatly affect the cost of the boiler, the greater strength obtained at the longitudinal joints enabling a lighter plate to be used to withstand a given pressure. The water tubes patented by the firm are now being very extensively adopted, upwards of 30,000 of them being at present at work, and about 250 being now

made weekly. These tubes have been introduced upwards of fifteen years, and the patent for them was renewed by the Lords of the Privy Council in March, last year. Amongst other firms, Messrs. Titus Salt, Sons, and Co., of Saltaire, and Messrs. James Wrigley and Sons, of Bury, have replaced the multitubular and two-flued boilers which they had in use with others of Messrs. Galloway's construction.

"The 'Galloway' tubes are tapered, and are made out of a single plate flanged over at the ends for attachment to the flues. They can be used either in boilers such as we have described, or in ordinary Cornish boilers, and, in addition to promoting the circulation of the water, and giving additional heating surface, they materially strengthen the flues. Messrs. Galloway and Co. have recently supplied seven water-tube boilers to Messrs. Hopkins, Gilkes and Co., of Middlesbrough. These boilers, which were 18 ft. long by 5 ft. 6 in. in diameter, with an oval flue from end to end, being heated by the waste gases from the puddling furnaces, and being found to work very satisfactorily. The other ordinary boilers used by Messrs. Hopkins, Gilkes and Co. are 20 ft. 3 in. long by 4 ft. 6 in. diameter, and have a single flue 2 ft. 1 in. in diameter dropping down at one end to join the furnace flue."

5. *American Vertical Tubular Boiler*.—From the "Scientific American" we arrange the following description of a boiler which presents some features of novelty. "The hindrance of the deposition of sediment and scale in a boiler, by a circulation of the water during the process of steam generation, and the utilization of a large amount of the heat, are objects worthy the attention of all who desire to render the use of steam power more general and effective than heretofore. Such is the design of this new boiler. This boiler consists of a cylindrical shell, with an internal fire-box, also cylindrical, the two being connected together by stay bolts in the ordinary manner. From the crown sheet of the fire-box is suspended a water leg, or cylindrical box, (A) the exterior surface of which is armed with a series of bent pipes, opening into its interior at both top and bottom. The products of combustion are carried off by vertical tubes (C), passing from the crown sheet to the top of the boiler, where the stack is commenced, with an inverted funnel covering the whole; or, in the

case of boilers of large size, a smoke box is formed of brick-work communicating with the chimney at the side. The bottom of the water leg is connected with the exterior water space by means of horizontal tubes (D), which assist the circulation of the water. Opposite the end of each of these, in the external shell, is a handhole (E), which may be used to clean them, or to draw out any scale or dirt from the bottom of the leg. A steam drum (F), of any convenient form, is attached to the top or at the side of the boiler, as the case may require. The principle of construction is equally applicable to large or small boilers, and it has been thoroughly tested, and with very satisfactory results, in both. It is readily repaired in case of the tubes giving way, by taking out the horizontal pipes which join the water spaces, and disconnecting the interior leg at the crown sheet. The connection at this point is made by means of a cast-iron ring with gasket and screw bolts, which, being in the water space, are protected from fire, and the joint can therefore be readily broken, and the whole leg, with its attached water pipes, dropped down into the pit below, where it can be worked upon on all sides. The horizontal pipes are easily replaced by means of the hand-holes in the shell. The advantages of this arrangement are in the interior fire-box, in which no heat is lost by contact with brick-work; in the thorough circulation of the water of the boiler, secured by the water tubes surrounding the water leg; and by the horizontal tubes connecting the exterior and interior water spaces; in the entire consumption of the fuel, and exhaustion of the heat, caused by the ample size of the combustion chamber, as shown by the fact that the gas, when leaving the boiler, is comparatively cold, and in the superheating of the steam by the tubes at the top, passing through it for a short distance after leaving the surface of the water. The effect of the circulation of water in this boiler is such that, in those which have been for some time in use, it was found that although the water used was impure, the interior of the boiler was clean and free from scale. Those conversant with the subject will readily understand that the large fire surface and rapid circulation of water, secured in this contrivance, must produce great economy in the use of fuel, and this has, in fact, been found to be the result. In addition to this, the boiler has the great advantage of being

compact and readily handled. It requires no brickwork to set it, and is therefore recommended for shipment to the south or to distant points, where brick and lime are difficult to procure."

We believe that a boiler upon this principle has been ordered by the Commissioners of the Great Exhibition to be held in Paris in 1867.

6. A paper on "*Riveted Joints*" was read before the "Society of Engineers," by Mr. Thomas Baldwin, and of which an abstract was published in the "Mechanics' Magazine;" this we here give. "Ask a boiler-maker why he places the rivets in a boiler 2 in. apart, and he answers, because 'it's the practice,' that is, because it is customary to do so. Ask the inspector of a boiler association the same question, and he, 'with his extensive experience and close observation of many hundreds of boilers,' tells you that 2 in. is the best distance, since all boiler-makers use it, and, further, if the rivets be placed at a greater distance apart, the joints cannot be made tight, and, if placed nearer together the metal left between the rivet holes will be too weak to bear the strain upon it. If, then, you say to these gentlemen, it has been found by experiment that a bar of iron 1 in. square used as a rivet will be sheared across by a force of 50,000 lb., and that a piece of boiler plate having a section equal to one square inch will be torn asunder by 51,000 lb., and that you conclude from these experimental facts that the area of the rivet and the area of the cross section of the metal left between the rivet holes should be nearly equal to make the strongest boiler, you are at once told that 'in theory it may be so, but it has been found that the plates are so much weakened by the use of the punch that nothing short of 2 in. will do for the pitch of the rivets.' If you ask to be referred to experimental data showing that this pitch under all circumstances is the best, you are simply told that experience teaches it, and this even by men placed in a position to advise the users of steam boilers as to the best method of construction. The author is, therefore, desirous of placing this matter fairly before those who spend large sums of money in steam boilers and yet get only 75 per cent. of the strength that correct principles of construction will give, and, therefore, pay 25 per cent. more for a boiler than is required, if these principles be attended to, or get a boiler that is 25 per cent. weaker than it ought to be. However strange it may seem, a boiler

made of $\frac{3}{8}$ in. plates and put together with $\frac{3}{4}$ in. rivets and 2 in. pitch is just as strong as a boiler made of $\frac{1}{2}$ in. plates with the rivets and pitch the same as used for the $\frac{3}{8}$ inch plates, for both would give way by the rivets being sheared across, which causes the user of a boiler to pay 25 per cent. more for his boiler than he ought to pay.

We will now try to ascertain and confirm, by mathematical demonstration, what ought to be the proper pitch to get the strongest riveted joints for steam boilers from the least material, when the thickness of plates and the diameter of the rivets are given. As mathematical demonstration is by far the shortest and simplest way of arriving at the required result,

Let P = pitch of the rivets in inches.

d = diameter of the rivets in inches.

a = area of one rivet in inches.

t = thickness of plates in inches.

s = number of pounds required to shear one square inch of wrought iron in the form of rivets.

n = number of pounds required to tear asunder one square inch of the boiler plate, left between the rivet holes after punching.

Then the sectional area of the plate between any two rivet holes is

$$= (P - d) t$$

and the force required to tear that section asunder is

$$= (P - d) t n \quad \dots \quad \dots \quad \dots \quad (1)$$

The force required to shear one rivet across is

$$= a s \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

“Now, to economise material, and make the strongest single riveted joint, we must make the rivets just on the point of shearing across when the plates are just on the point of being torn asunder; thus (1) and (2) must be equal, or

$$(P - d) t n = a s \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

from which we get

$$P = \frac{a s}{t n} + d \quad \dots \quad \dots \quad \dots \quad (4)$$

and

$$n = \frac{a s}{(P - d) t} \quad \dots \quad \dots \quad \dots \quad (5)$$

“Now, Mr. Fairbairn has given a table for practical use, in which the thickness of the plates, the diameter of the rivets, and the pitch of the rivets are stated. Making $s = 50,000$ lb. which has been arrived at by experiment, and given on the authority of Professor Rankine, and making P , d , and t agreeable to Mr. Fairbairn's table, we find by equation (5) the values of n in table I., column 5.

TABLE I.

Given in Mr. Fairbairn's table.			By equation (5).	
Plate t in.	Rivet d	Pitch P	a	n
3·16	·375	1·25	·11044	33670
$\frac{1}{4}$	·500	1·50	·19635	39270
5·16	·625	1·625	·3068	49088
3·8	·75	1·75	·4417	58893
$\frac{1}{2}$	·8125	2·00	·51849	43666
5·8	·9375	2·50	·6903	35346
$\frac{3}{4}$	1·125	3·00	·994	35343

“The values of n , shown in the last column, are very variable indeed, attaining a maximum in the case of $\frac{3}{8}$ in. plates amounting to 58,893 lb., while the experiments made by Mr. Fairbairn on the tensile strength of boiler plates, and given in his paper read before the Society of Arts in November, 1864, give the mean value of $n = 52,486$ lb., and yet we find the values of n as deduced from $\frac{1}{2}$ in. plates from Mr. Fairbairn's table amounting only to 43,666 lb., and for 5-16in. plates as low as 39,270 lb., a discrepancy quite unaccountable. The common practice of making the distance between the rivets 2in. for $\frac{3}{8}$ in. plates with $\frac{3}{4}$ in. rivets gives by equation (5) the value $n = 51,041$ lb., which is a close approximation to the strongest form of joint for single riveted plates. If n be taken of the same value as Mr. Fairbairn recommends for $\frac{3}{8}$ in. plates, we have by equation (4)—

$$P = \frac{a s}{t n} + d = \frac{.4417 \times 50000}{.5 \times 58893} + .75 = 1.5 \text{ in.} \quad \dots \quad (A)$$

But if the pitch of the rivets for $\frac{3}{8}$ in. plates be 2 in., then $n = 51,041$ lb., with $\frac{3}{4}$ in. rivets and $\frac{1}{2}$ in. plates we get

$$P = \frac{.4417 \times 50000}{.5 \times 51041} + .75 = 1.615 \text{ in.} \quad \dots \dots (B)$$

Mr. Fairbairn gives a number of experiments on single riveted joints (in the 'Philosophical Transactions' for the year 1850, and in his 'Useful Information for Engineers'), the thickness of the plates used being 22 in., and 3 in. broad, put together with $\frac{1}{2}$ in. rivets. The mean breaking weight of all the experiments is given at 18,590 lb. The area of the two rivets being $2 \times .19635 = 3927$, and the sectional area of the plates after punching = $3 - 1) \cdot 22 = .44$, from which we get

$$n = \frac{18590}{.44} = 42250 \text{ lb.}$$

which, being used for $\frac{1}{2}$ in. plates with $\frac{3}{4}$ in. rivets, we have by (4)

$$P = \frac{.4417 \times 50000}{.5 \times 42250} + .75 = 1.795 \text{ in.} \quad \dots \dots (C)$$

Mr. Fairbairn's experiments with plates .22 in. thick, $3\frac{1}{2}$ in. broad, fastened together with three rivets $\frac{1}{2}$ in. in diameter, gives

Area of the three rivets	...	...	= .589 in.
Area of plates, deducting rivet holes	...	...	= .44 in.

which broke through the line of rivets by 19,675 lb., giving

$$n = \frac{19675}{.44} = 44534 \text{ lb.}$$

Had these plates been 4.178 in. broad instead of 3.5 in., the section of the plate after punching would have been $2.678 \times .22 = .589$, equal to the area of the three rivets, and the riveted joint much stronger—the ratio of strength being nearly as 100 to 84. But experiments made on only two or three rivets is no fair criterion, as Mr. Fairbairn has suggested, for he concludes that the strength of a single riveted joint, including the rivet holes in the measurement of the section of the plate, is fairly represented by a breaking strain of 34,000 lb. on the square inch of such section. Now the entire section of the plate used in the experimental inquiry, with two rivets, was $3 \times .22 = 66$ in., and the section of the plate after deducting the rivet holes will be $(3 - 1) \cdot 22 = 44$ in.; we then have

$$n = \frac{34000 \times .66}{.44} = 51000 \text{ lb.}$$

as the power of the riveted plates to resist a tensile strain.

Applying this value of n as before, we find, for $\frac{1}{2}$ in. plates and $\frac{3}{4}$ in. rivets,

$$P = \frac{.4417 \times 50000}{.5 \times 51000} + .75 = .616 \quad \dots \quad \dots \quad \dots \quad (E)$$

The mean of these results for $\frac{1}{2}$ in. plates will be found to give $P = 1.63$ in. We therefore find that the shearing force and the tensile force are so nearly equal that, for practical purposes, they may be considered so; we can then dispense with s and n in equation (4), which becomes—

$$P = \frac{a}{t} + d \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (6)$$

which gives for $\frac{1}{2}$ in. plates and $\frac{3}{4}$ in. rivets—

$$P = \frac{.4417}{.5} + .75 = 1.6334 \text{ in.,}$$

nearly the same value as the mean of all the other deductions.

After Mr. Fairbairn has analysed his experiments, he says, 'If we take the mean of the experiments as respects the area of the rivets to that of the plates, we find one half in rivets about the proportion, or the area of the rivets in the last experiments should have been .4 in., which is nearly equal to the area of the plates through the rivet holes.' The following note is also attached:—'Subsequent experiments made for ascertaining the strength of rivets (*vide* experiments on the strength of rivets for the Britannia and Conway tubular bridges) fully corroborate these views, namely, that riveted joints exposed to a tensile strain are directly, or nearly so, as their respective areas, or, in other words, the collective areas of the rivets are equal to the sectional area of the plate taken through the line of rivets.'

Again, in his paper read before the Society of Arts, November, 1864, he says, 'In this estimate we must, however, take into consideration the circumstances under which the results are obtained, as only two or three rivets came within the reach of experiment; and again looking at the increase of strength which

might be gained by having a greater number of rivets in combination, and the adhesion of the two surfaces in contact, which, in the rivet joints compressed by machine, is considerable, we may fairly assume the following relative strengths as the value of plates with their riveted joints,—

'Taking the strength of the plate at	...	...	...	100
The strength of the single riveted joint will be	...	...	...	56.'

Now we find, by equation (6), for all practical purposes, s and n are so nearly equal that they may be neglected, and that

$$P - d = \frac{a}{t} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (7)$$

Then we have $100 : 56 :: P : P - d$; but it has been shown that the area (a) of the rivet must enter into the calculation, and if we substitute the equivalent of $P - d$ from (7) we get

$$100 : 56 :: P : \frac{a}{t}$$

$$\therefore P = 1.7857 \frac{a}{t} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (8)$$

which for $\frac{1}{2}$ in. plates and $\frac{3}{4}$ in. rivets gives

$$P = 1.7857 \frac{.4417}{.5} = 1.5774 \text{in.} \quad \dots \quad \dots \quad \dots \quad (F)$$

Or substituting the value $.7854d^2$ for a in (8), we have

$$P = 1.4 \frac{d^2}{t} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (9)$$

This expression for the distance of the rivets is therefore deduced from Mr. Fairbairn's estimate of the whole of his experiments, and gives values differing from Mr. Fairbairn's table given in his paper, and before quoted. Now Mr. Fairbairn gives distances for rivets, which, he states, he finds the best in practice, yet at the same time they do not agree with his deductions from experiment. No one will doubt the importance of having the shells of boilers made of the strongest possible construction. When the single riveted joint is used, and the thickness of the plates and diameter of rivets given, we have seen that the true pitch of the rivets is given sufficiently near for practical

purposes by equation (6), and also again as deduced from Mr. Fairbairn's estimate of his own experiments by equation (9). A table, giving the pitch and diameter of the rivets and the thickness of plates, will be found below, containing the results of both these investigations.

TABLE II.

Thickness of the plates in inches.	Diameter of the rivets in inches.	Area of the rivets in inches.	Pitch of the rivets in inches. Equation (6)	Pitch of the rivets in inches. Equation (9)
t	d	a	$P = \frac{a}{t} + d$	$P = 1.4 \frac{d^2}{t}$
$\frac{1}{4} = .25$	$\frac{1}{2} = .5$	.1963	1.2854	1.4025
5-16 = .3125	5-8 = .625	.3068	1.6067	1.7528
3-8 = .375	$\frac{3}{4} = .75$	.4417	1.9278	2.1033
7-16 = .4375	$\frac{3}{4} = .75$	.4417	1.7596	1.8031
7-16 = .4375	13-16 = .8125	.5185	1.9976	2.1159
$\frac{1}{2} = .5$	$\frac{3}{4} = .75$	.4417	1.6334	1.5774
$\frac{1}{2} = .5$	13-16 = .8125	.5185	1.8496	1.8513
$\frac{1}{2} = .5$	7-8 = .875	.6013	2.0776	2.1471
9-16 = .5625	13-16 = .8125	.5185	1.7343	1.6456
9-16 = .5625	7-8 = .875	.6013	1.9439	1.9086
9-16 = .5625	15-16 = .9375	.6903	2.1647	2.1910
5-8 = .625	15-16 = .9375	.6903	2.0420	1.9729
5-8 = .625	16-16 = 1.	.7854	2.2566	2.2436

The fourth column of the last table seems to be entirely trustworthy as to the pitch of the rivets, since the relations of the strains are more uniform than would be the case if the formula of the last column was used. Where the holes are punched, their mean diameter should be taken in fixing the pitch, as the taper of the hole reduces the area of the metal between the rivet holes, and it is only necessary to increase the pitch by the amount the mean diameter exceeds the diameter of the punch."

7. On the important subject of *Boiler Seams* as affecting their safety, we give the following paper from the "Engineer." It refers to and takes up the consideration of several points discussed in the paper read before the Society of Engineers, of which we have in the previous paragraph given an abstract. "In the present position of the engineers' art it is practically

impossible to put together the component parts of any structure of wrought iron—bridge, ship, roof, or boiler—without using rivets; and it is certain that the rivet must continue to play a most important part until some efficient and economical system of welding plates has been introduced, and its value tested by experience. The direct result of the almost exclusive use of the riveted joint is, that the strength of every wrought-iron structure is measured and determined, not so much by the tensile strength of the plates as by the laws determining the resistance to shearing offered by a rivet, and by the resistance to tearing offered by a section of plate which has undergone a process which admittedly weakens the iron according to some excessively ill-defined law. It is perfectly well known that very anomalous and contradictory results have been obtained by different experimenters who have undertaken the task of rendering it possible to express this law, and the general problems connected with the strength of riveted joints, by a numerical formula; and it is certain that contributions to our knowledge of the subject are urgently needed. We have no doubt, therefore, that Mr. Baldwin's paper will be carefully perused, especially by students. We wish we could add, with advantage. It will be seen at a glance that the paper treats almost exclusively of the means of determining the best pitch for the rivets of boiler seams. The author's remarks are therefore, and properly so, confined to but one section of an important subject; and in considering his propositions we cannot do better than follow his example. It will not be necessary here to say much as to the value of the formula which he has prepared. They are based, from first to last, on assumptions which are practically erroneous—whether they are equally erroneous in theory or not is quite beside the question—and this fact, as a matter of course, renders his calculations almost valueless. The paper begins with the assertion that the universal pitch adopted by all boiler makers is two inches, and goes on to state that as 'a bar of iron one inch square will shear at 50,000 lb., while a plate having a section of one square inch will be torn asunder at 51,000 lb., it is natural to conclude from these *experimental facts* that the area of the rivet and the area of the section of plate left between the rivet holes should be identical.' And in the next paragraph we are told that a boiler of $\frac{3}{8}$ in. plate,

made up with $\frac{3}{4}$ in. rivets, put in with a 2 in. pitch, is just as strong as a boiler made with $\frac{1}{2}$ in. plates, the rivets and pitch remaining unaltered. From this it is further deduced as a species of corollary that those who purchase boilers with $\frac{1}{2}$ in. plates pay 25 per cent. more than they need to spend. The remainder of the paper is occupied with what is intended to be a demonstration of the truth of the second proposition. Now the very first statements contained in Mr. Baldwin's paper are contrary to fact, and appear to have been written in the absence of any general knowledge of the practice of boiler making. It is perfectly true that a pitch of two inches is very commonly adopted for $\frac{3}{8}$ in. plates and $\frac{3}{4}$ in. rivets, but it is equally true that such a pitch is by no means so universally employed as Mr. Baldwin would have us believe. In the Staffordshire mining districts for example, where hundreds of boilers of all sizes are made yearly, a 2in. pitch with $\frac{3}{8}$ in. plates is rather the exception than the rule. Boilers are principally made there under a peculiar jobbing system which renders it necessary that a minimum of work be expended upon them; but nearly all the work expended upon a boiler is represented by punching and riveting, and therefore the wider the pitch the cheaper will be the boiler. As a result, boilers with $\frac{3}{8}$ in. plates are usually put together in Staffordshire with $\frac{3}{4}$ in. rivets spaced $2\frac{1}{4}$ in. apart, while a $2\frac{1}{2}$ in. pitch is in no way unusual. The price of the boiler is thus kept down, and we believe it can be proved that a boiler with plates and rivets of the specified thickness and diameter is stronger if made with a $2\frac{1}{2}$ in. pitch than it would be with a pitch of 2 in. It is not necessary, however, to confine ourselves to Staffordshire for illustrations of the fallacy of Mr. Baldwin's assumption. We have now before us a specification for an express engine on the London and North Western Railway, in which it is stipulated that the plates of the barrel shall be of the best Lowmoor iron, $\frac{3}{8}$ in. thick, put together with $\frac{3}{4}$ in. rivets, spaced $1\frac{3}{4}$ in. from centre to centre. In marine work, on the contrary, the pitch for $\frac{3}{8}$ in. plates is seldom less than $2\frac{1}{4}$ in., frequently $2\frac{1}{2}$ in. The accuracy of this fact is testified to by specifications from Clyde makers and others in our possession. It is unnecessary to further enlarge on the point. So far from 2 in. being an invariable pitch, nearly every boiler maker has a rule of his own, which he rigorously observes under

all circumstances. In point of fact it would be injudicious to put forward any one pitch as the best for any particular thickness of plate. The pressure at which boilers are worked is invariably far within the strain which would be required to tear a seam open; and the first consideration is not so much that the boiler should be strong as that it should be tight. There is scarcely a single instance on record of a boiler giving way by the tearing of seams, where the metal had not previously been weakened by corrosion, or by some such congenital defect as a crack in a plate caused by faulty punching. The closer the pitch the easier it is to make a seam tight, and therefore in all cases where the boiler is exposed to strains or jars, as, for instance, in the case of a locomotive, a close pitch is desirable; while in marine work, where the pressure is very moderate, and in stationary boilers, which are free from the influence of vibration, a wider pitch may be adopted with advantage; and these considerations are habitually regarded by those who design boilers with a competent knowledge of the subject, whatever Mr. Baldwin may think. The second proposition, that in buying a boiler with $\frac{1}{2}$ in. plates in preference to one with $\frac{3}{8}$ in. plates, we spend 25 per cent. too much, is so obviously incorrect, and so completely ignores the existence of the destructive influences to which boilers are exposed, that we feel no little surprise that it should have been advanced by one who has apparently been on intimate terms with boiler inspectors. All boilers, unless burnt out by shortness of water, fail from corrosion; they die of old age, and it should be obvious that the thicker a plate the longer it will resist destructive influences. Provided the plates in a $\frac{1}{2}$ in. boiler are of the same quality as those in a $\frac{3}{8}$ in. boiler, the former will last just as much longer than the latter as the plates are thicker. We do not now refer to fire-box crowns or sides. In all places where the iron is exposed directly to a very high temperature there is reason to believe that the thinner the plate, within reasonable limits, the longer it will last. But the question must not be regarded from this point of view when we have shells to deal with. A thick plate on a seating wall will last longer—other things being equal—than a thin plate, and Mr. Baldwin, if he had had much experience in the working of boilers, must have learned that a $\frac{3}{8}$ in. boiler will often cost more for repairs dur-

ing its lifetime, as compared with a $\frac{7}{16}$ in. boiler, than would have made up the original difference in price twice over. The strength of the seams is not the only question to be considered in putting down a boiler, and even though it were, Mr. Baldwin's conclusion that a $\frac{3}{8}$ in. boiler is as strong as one of $\frac{1}{2}$ in. plate would be none the less contrary to fact. The most cursory examination will serve to show that all the author's arguments are based on the assumption that the rivet and the plate are of equally good quality, not only originally, but after the operations of punching and riveting have been performed. If it can be shown that this equality does not exist, then are the author's conclusions erroneous. If the iron of the rivet is injured by the hammering it undergoes when the seam is being closed, then the pitch must be reduced; if, on the contrary, the plate is injured by punching, the pitch must be increased. In other words, a 2in. pitch for a $\frac{3}{8}$ in. plate, with a $\frac{3}{4}$ in. rivet, is only correct on the assumption that plate and rivets are of equally good quality; and if it can be proved that the plate is injured by being made into a boiler, then it follows that the pitch being limited—in order to make the seam tight—the plates must be thickened, and hence that a $\frac{3}{8}$ in. boiler cannot be as strong as one of $\frac{7}{16}$ in. or $\frac{1}{2}$ in. plate. There is no very reliable evidence in existence to prove that the iron of a rivet is weakened, as far as regards its power of resisting a shearing strain, by the treatment it undergoes when a boiler is being put together. There is little room to doubt that it is injured more or less, but, whether more or less, it is at least certain that the deterioration is trifling as compared with the mischief wrought on the plate by punching. Mr. Barnaby put this fact in a very clear light in the course of the animated discussion which followed the reading of the paper under consideration. Indeed, the fact that plates undergo much injury in the process of punching as commonly performed is well known to all who have tested riveted joints. Thus while the solid plate has been found to require a strain of 25·8 tons to break it, the same plate, when punched, has given way through the rivet holes with a strain of but 18·9 tons per inch of section, the value of the plate being thus reduced 25 per cent.; and this may be taken as a favourable example selected from dozens of trials. Experiments carried out with much care by the Government show that

a $\frac{3}{4}$ in. rivet of good iron will shear with a strain of 10 tons. This proportion of strength to diameter varies so seldom that such of our readers as are not familiar with the statement will do well to commit it to memory. A resisting power of 10 tons in a $\frac{3}{4}$ in. rivet corresponds approximately to a resisting power of 22.5 tons per inch in the unpunched plate, and the section of plate which remains between the rivet holes should exceed this strength if the rivets are to measure the resisting powers of a boiler of the given proportions. But we have seen that in one experiment the value of the plate was but 18.9 tons, while a series of experiments carried out by the Admiralty gave the value of different samples, after punching, at different figures varying between but 12.4 tons and 13.6 tons, the mean of the series being 13.2 tons, representing a loss of 37 per cent. in the samples tested, due to punching. Facts such as these are not new to engineers; but we think it possible that the precise figures we give—for which we are indebted to Mr. Barnaby—may be. Every one who has written on the subject of the strength of wrought iron structures cites experiments going to show that plates are invariably injured by punching; and we find it difficult to understand how, in the face of these facts, Mr. Baldwin can state that the strength of a rivet being 50,000 lb., that of the plate will be 51,000 lb., and accordingly proceed to base an important theory upon it. It is obvious that so far from 2in. being too large a pitch, it is too small, and that as we have already stated, a $\frac{3}{8}$ in. boiler with $\frac{3}{4}$ in. rivets and a $2\frac{1}{2}$ in. pitch will be stronger than if the pitch were reduced to 2in., and it will certainly be cheaper. Whether the seam can be made equally tight is quite another question, depending for its solution mainly on the purpose for which the boiler is intended. Even though it could be proved to demonstration that a plate lost nothing in value by being punched, still the paper would be imperfect, because the author's conclusions do not take cognisance of the fact that very frequently the rivets are far superior in quality originally to the plates. Thus we have ourselves used Lowmoor or Bowling rivets to put together best best Staffordshire plates; the tensile strength of the rivet iron being at least one-third greater than that of the plate. Rivet iron of the best quality is frequently thus used in order that the pitch may be increased,

and the cost of workmanship reduced. Indeed, under any circumstances, it is false economy to use inferior rivet iron; and the harder and more stubborn the plate the better should be the rivet. Good rivets can be knocked down with much more certainty and much less labour than those of inferior quality, and the extra price of the iron will be much more than repaid under ordinary circumstances. It is by no means easy to lay down any invariable rule for determining the best pitch for rivets, and formulæ of any kind can prove of little general service. They may be rendered useful as guides, but nothing more. In nearly every shop in the kingdom there is some general rule observed, but they do not agree with each other, and it may be easily proved that considerable differences in practice are not productive of appreciably variable results. In point of fact, the value and safety of a boiler depend far more on the tightness of the seams than on their strength, the difference between the actual and the bursting pressure being very considerable; and as it requires unusually good workmanship to make a boiler seam tight if the rivets are widely spaced, it appears to be advisable to sacrifice a little strength in order to secure so desirable a result. The duration of a boiler is nearly always determined by the progress made by corrosion, and the tighter the seams the less the prospect of injury, from the outside at least. There cannot be the slightest question that a $\frac{7}{16}$ in. boiler is stronger and better in every respect than a $\frac{3}{8}$ in. boiler, the pitch and diameter of rivets being the same in each case—the first being 2in., and the diameter $\frac{3}{4}$ in. Except as regards the fact that a thick plate will last longer than a thin plate under the influence of corrosion, it does not appear that much is to be gained by increasing the thickness of a boiler above $\frac{7}{16}$ in. A $\frac{1}{2}$ in. plate cannot be made tight with $\frac{3}{4}$ in. rivets, and it is probable that a thick suffers more from punching than a thin plate. Thus both the diameter of the rivets and the pitch must be altered, and the balance between plate and rivet again overturned. A $\frac{7}{16}$ in. boiler, double riveted, is stronger than a $\frac{1}{2}$ in. boiler single riveted, and, except when put to work under conditions which imply serious corrosion, it should be strong enough for any save exceptional pressures or diameters. It cannot be doubted that by drilling plates the strength is far less reduced than by punching them, a drilled

plate being at least 10 or 12 per cent. stronger than a punched plate; but it does not therefore follow drilled plates are best adapted for boiler work. In order to insure accuracy the plates ought to be drilled when *in situ*; but the action of the drill raises a burr between the plates which it is difficult to get rid of, and renders it yet more difficult to make the joint tight.—The best riveted joint which it is possible to make under any circumstances is immeasurably inferior to a welded joint, and to welded boilers we must come, sooner or later, and the sooner the better. A $\frac{3}{16}$ th welded joint is, possibly, stronger than a $\frac{3}{8}$ th riveted joint; and it is certain that $\frac{1}{4}$ in. welded boiler could easily carry pressures which would blow $\frac{3}{8}$ in. riveted plates to shreds. Welding plates is in no way a novel process; and it only needs a little well-directed energy and capital to render the system one of universal adoption. During the discussion on Mr. Baldwin's paper allusion was made to the cold rivet system extensively used in the United States of America. The boilers of the steamboats on the Western rivers carry tremendous pressures, but hot rivets are scarcely ever used in their construction, and no difficulty is experienced in making the seams tight. For the cold rivet it is claimed that the holes must be well filled, as there is no diametral contraction due to the cooling of the rivet; and that as a bad rivet is certain to split under the hammer, not only must first-class iron be used, but each rivet undergoes a test which proves whether it is or is not made of first-class iron. This is about all that is urged in favour of the plan. We know that many readers will refuse to believe that the holes are not filled when hot rivets are used; yet there is good reason, too, for asserting that they are not. Mr. Roberts, of Millwall, tried several experiments with both hot and cold rivets. He planed down a joint until he got a cross section of the rivets, and he invariably found, that when the aggregate thickness of the plates—representing the length of the rivet from just under the head to just under the snap point—exceeded three diameters, the rivet did not fill the hole at or about the centre of its length. It is possible that a very highly heated rivet in cooling may be so strained as to undergo a permanent reduction in diameter; but it is more reasonable to conclude that in the cases cited by Mr. Roberts the rivet was not upset toward the middle of its length,

and being but a moderately tight fit in the hole, hot, of course did not fill it at all when cold. It is worth considering whether the use of hot rivets affects the strength of the punched edge of the plate in any way, and it is to be regretted that very few if any experiments have been undertaken to test the relative strength of rivets made up respectively on the cold and hot rivet systems."

8. As a cognate subject to that discussed in two last paragraphs,—*Welded Joints in Locomotive Boilers*,—and one involving many important considerations, we take from the "Mechanics' Magazine" the following remarks:—"Amongst the numerous causes which lead to the explosion of locomotive boilers constructed in the ordinary way with lap joints, none contribute more largely to swell the category of accidents than corrosion of the plates. This corrosion is usually confined to particular localities, being found principally round the smoke-box end of the boiler barrel, in the interior, opposite to the edge of the outside angle-iron, when an annular groove is found to be eaten out of the plates by corrosion. A similar grooving also takes place along the edge of the inside lap at the longitudinal joints, and likewise at the transverse circular joints. This grooving, however, only occurs below the water-line, thus showing it to be the result of a chemical action. But the peculiar direction of the grooving, which invariably chooses for its locality the line of a seam of rivets, is not to be accounted for upon chemical principles; we must look for a mechanical cause. It can only be attributed to the springing of the plates of boilers when under pressure, whereby the metal at the joints becomes bent in consequence of the plates not being originally in the line of strain. As expansion and contraction are continually succeeding each other in the boiler, the scaly deposit is constantly being broken off at the edges of the joints. The plates are thus laid bare by this mechanical action at the lines of the joints, and thus the metal is kept continually exposed to the corroding action of the water instead of being protected by the scale. Corrosion is, of course, to be found in other parts of the same boiler, but then it is very limited in extent as compared with the grooving at the seams. In the former case, the surfaces of the plates are only irregularly over pitted; in the latter, deep channels are eaten

into the metal, sometimes leaving it on the outside as thin as a sixpence. This corrosion sometimes goes on so rapidly that plates will require renewal after only a few years' work, whilst pitting may continue for a number of years before it becomes dangerous. The details of construction of a locomotive, too, exert an influence upon it with regard to grooving. Rigid attachments are found to offer special points of resistance to the expansion of the boiler when under pressure, and so to increase the local action to a serious extent. The defects arising from riveted lap joints are, however, capable of remedy, by constructing the boiler on different principles. On the London and North-Western Railway each length of the barrel of the locomotive boilers is formed out of a single plate bent round into a complete circle, so as to have only one longitudinal joint instead of two. This joint is turned to the upper side of the barrel, so as to be in the steam space above the water-line, and thus the difficulty of corrosion along the longitudinal joint is to a great extent overcome. But a still better method of construction is adopted on the Midland Railway. This consists in having the plates rolled with thickened edges. This plan, which is found to obviate the injury previously experienced from corrosion, was recently described by Mr. W. Kirtley before the Institution of Mechanical Engineers. The ordinary thickness of 7-16in. is preserved in the body of the plate, the edges being thickened to $\frac{5}{8}$ in., with a long gradual taper in the thickness about 4in. long. When the plate is flanged, in order to do away with the angle-iron, this taper ensures a gradual springing of the plate distributed over all that length instead of the sudden bending concentrated at one point. The transverse circular joints are also formed with a similar section of thick-edged plate. By this mode of construction additional strength is gained, as the increased thickness of the plates between the rivet holes compensates for the loss of section by the holes. An example of the practical working of this system is afforded by one of the Midland Company's engines, which had originally an ordinary boiler. After working eleven years and a-half this boiler was removed, the plates having become much grooved and pitted, and a new boiler, constructed with thick-edge plates, was substituted. The engine has continued to work with the new boiler for six years and a-half, to

the beginning of the present year, when an examination showed that the plates were free from grooving, although they were badly pitted.

“Although this is evidently a step in the right direction, and is clearly the means of preventing the evil of grooving, it does not, however, remove the injurious strains which must result wherever a lap joint is employed. This can only be done by making the barrel truly cylindrical and circular throughout; then the strains would be removed, and an important improvement effected. And this has been done on the Midland Railway, where they now weld the longitudinal joints of the three rings forming the boiler barrel, making them all exactly the same diameter, and uniting them to each other with flush butt joints. The meeting ends of each ring are turned in a lathe, and united by covering strips formed of welded flush rings, shrunk on over the joints and double riveted. On each of the centre plates strengthening hoops are also shrunk, which cross the longitudinal welded joints, and are secured by a few rivets. Thus the boilers are truly cylindrical at every point, and their circular form is in no way changed by any strain to which they are subjected. The soundness of this principle has been corroborated in a very remarkable manner by a Midland engine, the boiler of which was constructed with butt joints, all flush throughout, the transverse joints being covered by external hoops and the longitudinal by internal slips. This boiler was started in 1847, and has consequently been at work about nineteen years. The original boiler plates still stand, never having been repaired, and grooving has not taken place at the butt joints; a little irregular pitting on the inside of the plates being the only visible sign of deterioration. This remarkable freedom from the grooving so prevalent in ordinary boilers with lap joints, can only be attributed to the circumstance of different construction. In another engine, the boiler plates were found badly grooved at an angle-iron joint constructed in the ordinary way at the smoke-box end, whilst the rest of the joints, which were butt joints, were free from grooving. The thick-edge plates are flanged, bent, and welded by means of special machines, particulars of which we purpose laying before our readers next week.

“Various experiments have been made to test the tensile

strength of the welded joints, the results of which will compare well with those of riveted joints. Strips of plate were cut out across the weld from pieces taken from several boilers to form the opening for the steam dome. Three sets of strips were tested of 1 in., $1\frac{3}{8}$ in., and $1\frac{1}{2}$ in. respectively, each piece being $7\frac{1}{2}$ in. in length, and cut transversely to the weld, which was in the middle of each piece. In all twenty-three strips were tested, eleven of which broke in the weld, and twelve broke in the solid; the average breaking strength per square inch was 20·6 tons, a very fair average. There were also eleven strips of the same plates unwelded tested, and the result was an average breaking strain of 23·6 tons. It will thus be seen that more than half of the welded strips broke in the solid and not in the weld, and that the average breaking strength of the twenty-three welded plates was within one-eighth of the full strength of the eleven unwelded plates. It was also found by these trials that the worst pieces, including some cases of defective weld, had more than two-thirds of the full strength of the unwelded plates. Welded boilers are a little heavier and somewhat more expensive than the ordinary class of lap jointed, single-riveted boilers with angle-iron ends. In the new boiler the increase of weight is about $1\frac{1}{4}$ tons, which arises from the thick-edge plates, and from the hoops and joint strips. As regards cost of labour and material, the new boiler shows an increase of about £50 over the old one. The extra weight and cost, however, form no serious bar to the use of the system, which, when its advantages are taken into consideration, comes out much cheaper than the old system. The Midland Railway Company were not slow to recognise this fact, for they have had nineteen of these welded boilers in constant use for the last six years and a-half. The result has proved so satisfactory that this system of construction has been permanently adopted for the engines on this line. The fact of the safety of welded boilers ought to tell with other railway companies, some of whom, if not all, we hope to find imitating so good an example as that set by the Midland. We shall then hear of far fewer locomotive boiler explosions, whilst, at the same time, the irrepressible item of repairs will figure much smaller in railway accounts than heretofore."

9. In continuation of the important department of boiler con-

struction, we give here an abstract of an exceedingly valuable and practical article on the *Joints of Locomotive Boilers*, to which we are indebted to the pages of "Engineering." "For both the transverse and longitudinal seams of the barrel 'butt' joints, with outside covering strips, are decidedly the best. Lap joints alter their shape when subjected to a tensile strain, the pull upon them giving rise to distortion. This distortion takes place in both single and double-riveted lap joints, but is, of course, more marked in the former than the latter; in either it gives rise to a buckling or bending of the plates close to the joint, and thus tends to produce 'furrowing.' In the case of the transverse joints of a boiler, this bending action is to a great extent resisted by the curvature of the plates; but in the case of the longitudinal seams it has full play, and it is therefore in these joints that it is especially destructive. When two straight plates are united by a joint-strip, and subjected to a tensile strain, a similar distortion takes place to that which occurs when a lap joint is similarly strained; in fact, the 'butt' behaves in this case like two lap joints placed close together. Where a joint-strip is applied externally to one of the longitudinal seams of the barrel of a boiler, however, the case is different, the tendency which the boiler has to bulge at the joint, correcting, to a great extent, the distortion which would otherwise arise. . . . To make a good butt-jointed boiler, the edges of the plates should be planed, and the rings forming the covering-strips of the transverse joints should be shrunk upon the boiler-plates with a slight tension; this tension will prevent them from becoming slack under the action of riveting. The longitudinal strips should have their ends thinned down, and placed under the transverse strips, these latter having pieces cut out to accommodate them. The arrangement of the junction of the two strips is shown at D, Fig. 3, where *a* is the transverse

Fig. 3.

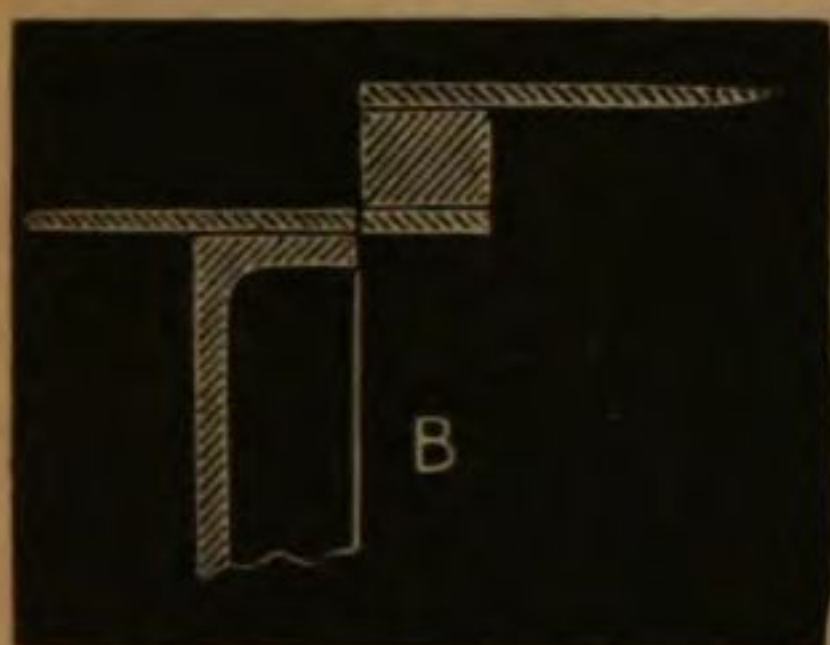


and *b* the longitudinal covering strip, *c* and *c* being the boiler plates. The thin end of the longitudinal strip should be suffi-

ciently long to take the nearest row of rivets in the transverse strip under which it is placed.

The connexion between the barrel and the smoke-box tube-plate is generally effected either by means of an external ring

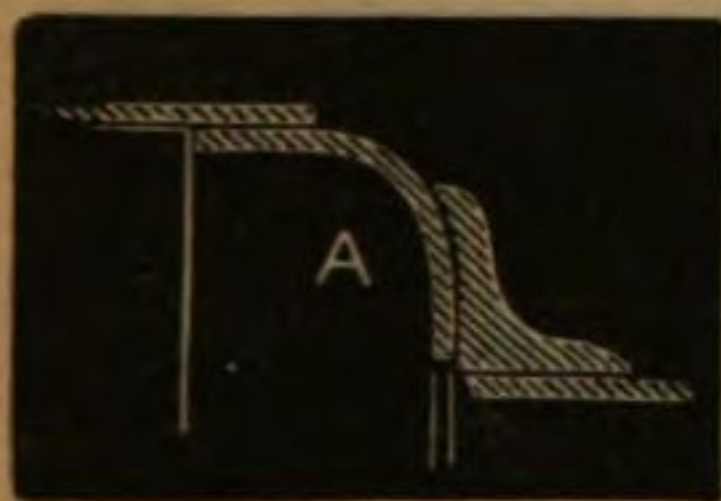
Fig. 4



of 3in. or $3\frac{1}{2}$ in. angle iron, or by flanging over the tube-plate and placing it inside the barrel, as shown at B in figure 4. When the former plan is adopted, all the rivet-holes in the angle iron ring should be marked off from those in the barrel-plates and tube-plate, and should be drilled, not punched, so as to avoid all risk of splitting the angle iron. When

the tube-plate is placed within the barrel, as at B, Fig. 4, its edges should be flanged forward as there shown. Some makers flange the tube-plates backwards; but, when this is done, the joint between them and the barrel is very inaccessible. The tube-plate, after being flanged, should be turned up outside so as to be perfectly circular.

Fig. 5.



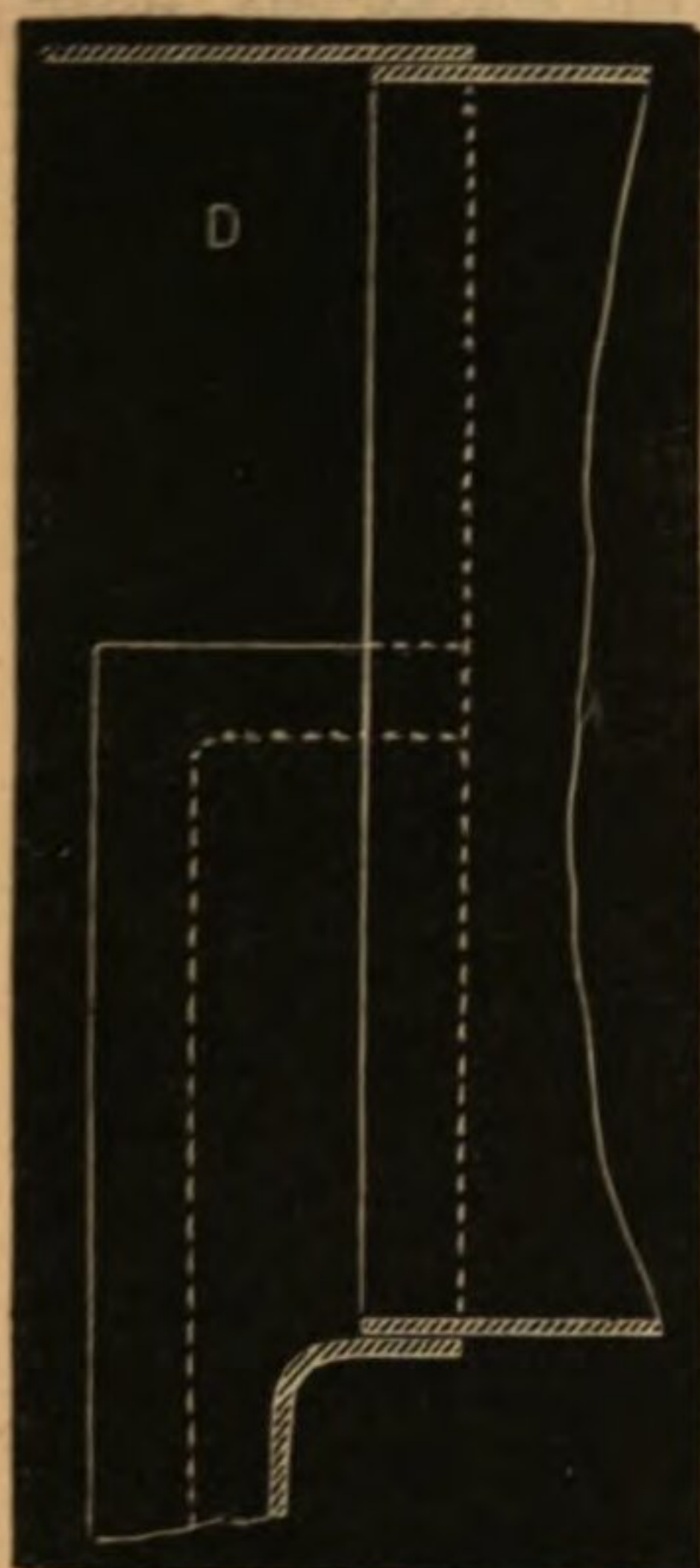
The manner in which the barrel is connected to the fire-box casing varies according to whether the top of the latter is raised above, or is flush with, the top of the barrel. That now most generally used in this country (where the former of the above cases exist), is shown at A, Fig. 5, the front plate of the fire-box casing being flanged back to join the side and top plates, and the barrel being

united to it by means of an angle-iron ring. The rivet-holes in this ring should be drilled in the same manner as we mentioned when speaking of the ring at the smoke-box end of the barrel.

When the top of the fire-box casing is flush with that of the barrel of the boiler, the two parts are generally united by one of the three methods, one of which is shown in Fig. 6. The arrangement of joints shown by D is that which has probably been most largely adopted. According to this plan, the sides of the front plate of the fire-box casing are bent backwards to join the side plates, whilst the upper edge is flanged forward for attachment to the barrel. The upper part of each side plate, and also

the top plate of the fire-box casing, are extended forward, so as

Fig. 6.



to lap over the barrel plates. In this arrangement the front plate of the casing is, in order to get it to the proper form, very much 'worked' towards the upper corners, and, unless great care is taken, flaws are a frequent consequence. The plan shown in Fig. 6, although not so neat in appearance as that just described, we have found to stand better and give less trouble; it is well adapted for use with a butt-jointed barrel. In this arrangement the front plate of the fire-box casing is merely bent backwards to join the side plates, the connexion between it and the barrel being effected by a bent-joint strip as shown in the figure. This joint strip may either be carried completely round the barrel, the upper part being reduced in width, or it may extend only a little past the centre line, a separate strip

being used to connect the barrel with the upper part of the fire-box casing. The joint strip uniting the front plate of the casing to the barrel is, of course, only bent at right angles for that portion of its length which is under the barrel; at the sides it opens out gradually, and eventually becomes flat, as shown in the figures. By adopting this mode of construction the front plate of the fire-box casing is merely bent at the sides, and, therefore, does not undergo any excessive working.

The connexion between the back plate and the side and top plates of the fire-box casing is a very simple one. The back plate may either (as is now generally done) be flanged over to join the other plates, in the same manner as the front plate, shown in Fig. 5. Square-cornered angle irons have been used in some cases to form the connexion, but their use is not to be recommended.

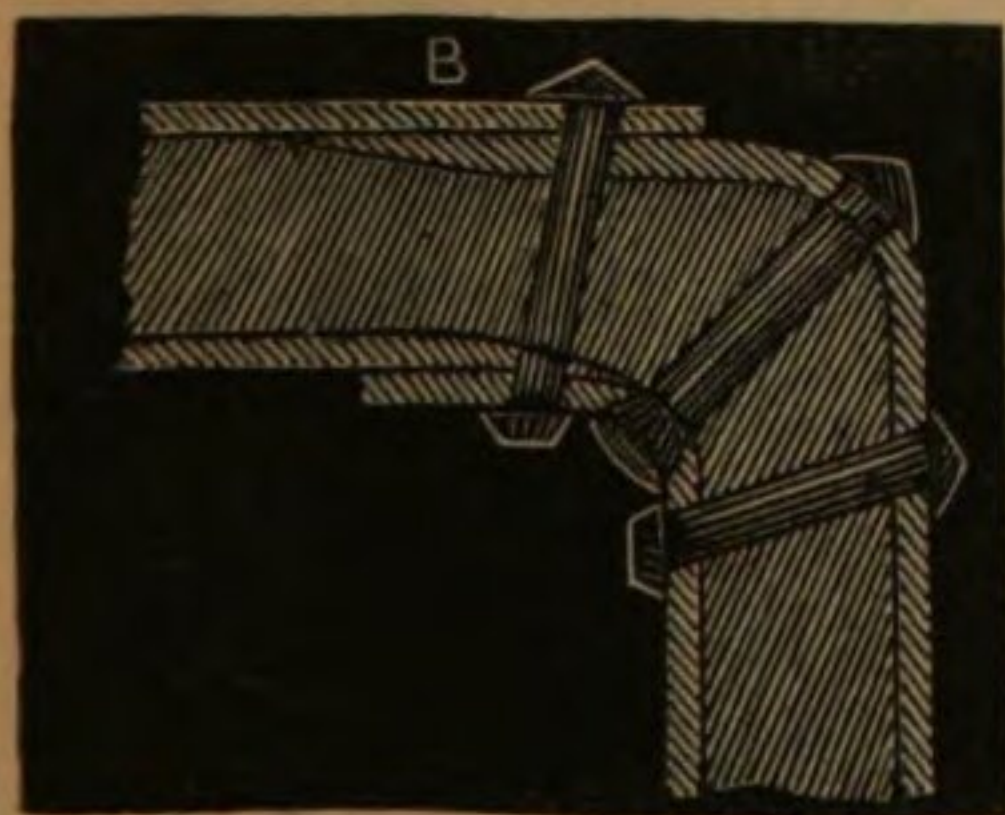
We must now consider the joints of the inside fire-box; these are the junction of the bottom of the fire-box with the outer

Fig. 7.



casing, and the joints of the fire-box plates themselves. Various methods of uniting the fire-box and casing are shown at H, I, J, K, and L, Fig. 7. According to the plan shown at H, a Z iron is introduced between the plates, whilst at I a very similar junction is effected by means of a pair of angle irons. Both these plans have the defect that the row of rivets passing through the plates of the inside fire-box is inaccessible, and, in addition to this, the plan shown at I is unnecessarily complicated. At J, the copper plates of the inside fire-box are shown set out at the bottom, so as to meet the plates of the casing. This plan has been largely used, and it makes a very good joint; it has, however, the objection of producing an awkward space for the collection of mud, and it does not allow mud-holes to be readily formed at the bottom of the water space. The joint now most generally used is that shown at K, a solid bar or ring being in this case introduced between the plates of the fire-box and casing, the rivets passing through the whole. By cutting away the ring, mud-holes can be readily formed at any desired points. A modification of this plan is shown at L, where a bent plate, or N iron, is substituted for the solid ring. The only advantage possessed by the N iron over the solid bar is, that it allows shorter rivets to be used for making the joints; on the other hand, it is more expensive, and less easily replaced if injured,

Fig. 8.



and it is difficult to manage at the corners. When the solid bar is employed, the rivets at the corners may be arranged as shown at B, Fig. 8.

It will not be necessary to say much about the joints of the fire-box plates. They are lap-joints, the tube and back plates being flanged over to join the side and top plates. As the tube-plate is much thicker than the other plates, it is a good plan to reduce the thickness of that part of it which is flanged over. This increases the space available for the accommodation of the tubes, and dimin-

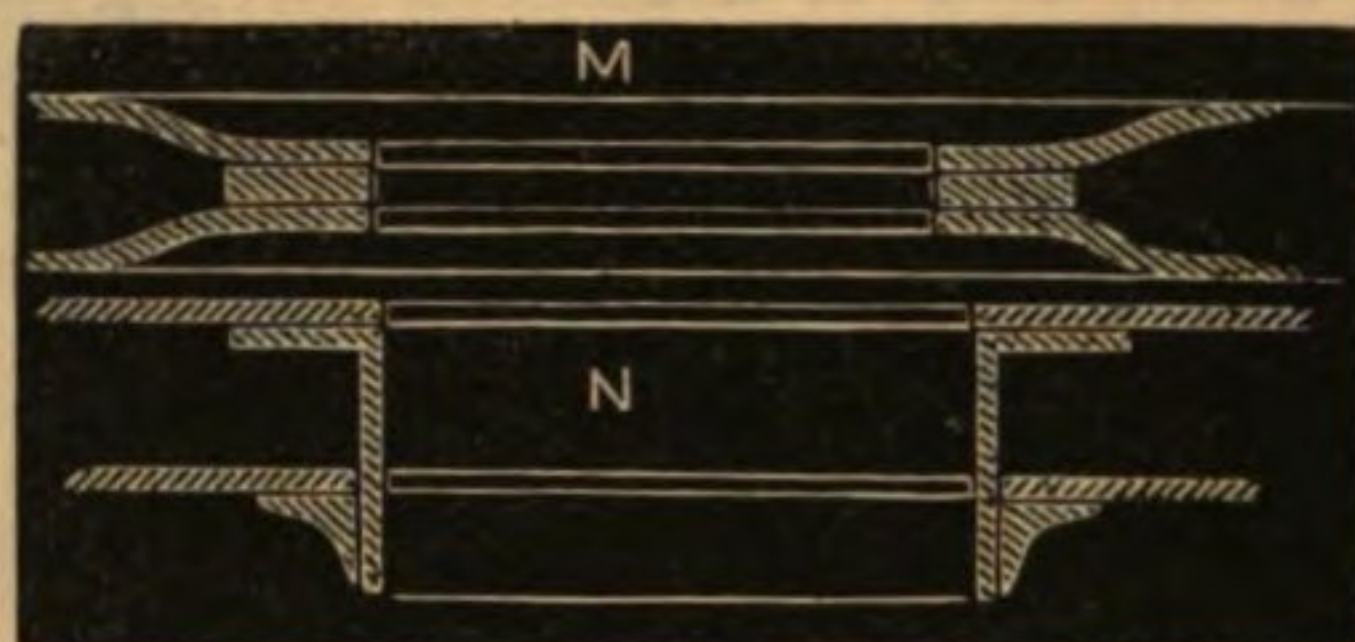
Fig. 9.



ishes the tendency of the plate to burn away at the joint. The reduction of the thickness of the plate should be so effected that it takes place gradually at the corner formed by the bending of the plate, as shown, C, Fig. 9.

At M and N, Fig. 10, are shown two ways of forming the fire-hole. According to the first plan, the plates of the fire-box and casing are riveted together through a ring placed between them, the thickness of this ring being reduced by setting in the plates. Very frequently the thickness of the ring is equal to the full distance between the plates, which

Fig. 10.



are in such cases left flat; but the joint made with the thin ring, however, generally stands better; the setting of the plates, however, makes it more expensive. According to the plan shown at N, a flanged mouth-piece is riveted to the outside of the fire-box plate; this mouth-piece passes through the plate of the fire-box casing, and is united to it by an angle-iron ring. We believe that this arrangement stands well; but, in the case of any repairs being required, the rows of rivets uniting the mouth-piece and angle-iron ring to the plates of the fire-box and casing respectively are rather inaccessible.

In all boiler joints it is important that the rivet-holes in the various plates and angle-irons should be perfectly fair with each other, and that they should be completely filled by the rivets. If they do not all correspond accurately, they should never be forced to do so by drifting; rivets should first be placed in those holes which agree properly, and the remainder should then be rimed out until a fair hole is obtained. Messrs. Adamson & Co., the celebrated boiler-makers of Hyde, have for a long time drilled all the rivet-holes of the stationary boilers made by them, the

plates forming the joints being bent to their finished form, and laid together whilst being drilled. There is no reason why the same system should not be carried out in making locomotive boilers; the question is merely one of expense, and we doubt very much whether the time and labour saved by having perfectly fair rivet-holes would not, to a very great extent, counterbalance the extra expense of drilling over punching."

10. *Romminger's Steam Generator*.—"The peculiarity of this steam generator," says the "Mechanics' Magazine," in an article of which the following is an abstract,—“Consists in the form and combination of a series of pipes in order to obtain the greatest possible heating surface combined with the smallest possible steam generating surface in a given space. For this purpose Mr. J. T. Romminger, of Dresden, arranges a system of pipes, which by their peculiar shape do not require the interposition of any heat-absorbing material, the smoke flue from the fire-grate to the chimney being produced by the form or transverse section given to the pipes. These pipes are made of cast-iron, and have a transverse section of a cross-like form. In some cases, however, the passage through these pipes is formed with a lining of wrought metal, which is introduced into a mould so as to have cast metal run thereon. The ends of these pipes are connected in such a manner as to cause the water which is forced into the entrance pipe to pass in succession through the whole of the pipes constituting a series. Further, he arranges the proportions of the series of pipes in a manner to produce an even pressure throughout, by giving the entrance a smaller size than the outlet. Metal rods are introduced into the pipes in cases where the water produces sediment, so as to cause by thus narrowing the passage a greater friction in the passage of the steam, by which means the pipes are kept clear of sediment, which is carried away by the steam. A hand pump is used when starting the engine, and another pump is driven by the engine when at work; so that for each stroke of the engine jets of feed water are introduced into the entrance pipe of the system, and this water traversing to and fro through the whole series of pipes, issues as steam of high pressure from the outlet at the opposite end of the series, and it then passes to the steam cylinder. In the case of a surplus of steam being generated it will escape through a safety

valve on the steam chamber, where a governor is applied to act on a valve, which when raised allows a portion of the feed water to pass without entering the generator until the proper speed of generating steam is again obtained. Each pipe being made in its transverse section of a cross-like form, when several are placed together side by side, and others are placed above them, longitudinal passages or flues are formed horizontally for the passage of the heat and products of combustion from the furnace; and by the forms of the ends of the pipes vertical flues or passages are also formed, so that the heat and products of combustion are caused to pass to and fro along the horizontal flues. In the engraving there are two tiers or rows of pipes, but more may be used if desired; these pipes are to be arranged within a chamber of firebricks, which is cased externally with iron, as is shown in the engraving, but this may be varied. At the upper part of the chamber is a reservoir for receiving water to be heated by the products of combustion after they have passed beyond the system of pipes constituting the steam generator. The water is first pumped or forced into the outermost pipe of the upper tier of pipes, from which it is caused to circulate to and fro in the pipes constituting such upper tier; the water then passes into one of the pipes of the lower series of pipes, and passes to and fro in succession through the pipes constituting such lower series, and the steam is conveyed away by a steam pipe from the last or outermost pipe of that series. The pump or apparatus by which the water is supplied is to be arranged in a suitable manner for supplying such a measure of water as is required for each stroke of the steam engine, as has before been done in supplying other arrangements of steam generators constructed of other forms of pipes or passages."

10a. *Heating Surface*.—For the following practically useful article we are indebted to "Engineering:"—"There is an anomaly in the fact that a square foot of cooling surface will condense a considerably greater weight of steam, in a given time, than a square foot of average heating surface will generate. It takes less surface to get the heat out of the steam than it took to get it in. The rapidity of condensation, where the heat has to traverse the substance of metal tubes, is astonishing. A great cylinder full of steam at a temperature often as low as 175° , and

seldom as high as 225° , is discharged, in a fraction of a second, into a surface condenser cooled by water at from 50° to 80° , and is itself turned to water almost in the very instant of its escape. The index of the vacuum gauge remains unmoved and apparently immovable. The whole difference of temperature between the steam side and the water side of the tubes is but from 100° to 150° , and yet with a rapid circulation of condensing water, and with clean surfaces, at least $21\frac{1}{2}$ lb. of steam are condensed per square foot per hour according to Peclet, while Dr. Joule's experiments have shown a condensation of even 100 lb. of steam for the same units of surface and time, the quantity varying with that of the condensing water. We are not here considering the mere rapidity with which steam will condense, but the rapidity with which heat is conducted through the metal of the condensing tubes. In the steam boiler we have a difference of temperature, between the fire side and the water side of the plate, varying from (say) $2,700^{\circ}$ in the fire-box to 300° or more near the smoke-box, and yet the quantity of heat which can be got through the plates and tubes, without injury or great waste, is not perhaps one-half that which is transmitted by the same area of condensing surface. There are differences, it is true, in the thicknesses of the plates and tubes respectively employed, and in the case of the boiler the iron may be more or less coated on one side with scale and on the other with soot. But so, too, the condenser tubes may be more or less furred with the greasy deposit which comes over from the cylinder. And we are not to forget that the currents of steam are much more subdivided in the condenser than are the currents of heated gases in the furnace and boiler-tubes.

"We have, of course, to bear in mind that the heat to be transmitted through the tubes of the condenser is not equal in amount to that generated in the furnace of the boiler. A portion of the heat is lost by radiation, and a further portion is transformed into work; yet so low, comparatively speaking, is the thermodynamic efficiency of the best steam engine, that by very far the larger proportion of all the heat generated in the furnace passes through the engine without being turned to account in work, and is thrown into the air, or into the sea, from the condenser. After making every allowance, we shall find that, when we take into

account the respective differences of temperature upon the two sides of the heating and cooling plates and tubes, the efficiency of the cooling surface greatly exceeds that of the heating surface. When we say cooling surface, we are aware that even this is really heating surface; in other words, the waste steam heats the water of condensation, and we may, therefore, state the case thus, that the conditions of condensation are apparently more favourable than those of evaporation to the rapid transmission of heat through the substance of metal plates and tubes.

“But the difference cannot, we think, be due to any difficulty in the reception of heat by water, since we know that the temperature of the furnace plate never rises sensibly above that of the water, and water may even be boiled, for a short time at least, in a paper tray, without burning the paper. If there were any difficulty in the disposal of the heat as fast as it came through the plate, the plate would itself be overheated, just as if we coated it on the water side with fire-clay. It is remarkable, indeed, how well, not only the plate, but often a considerable thickness of boiler scale at the back of it, transmits heat to the water. When we consider this, it appears doubtful whether any gain would accrue from a rapid artificial circulation of the water over the plate, as has been occasionally proposed, especially when we bear in mind that, with the exception of the entering feed water, the liquid contents of the boiler are of the same temperature throughout, and that one particle of water at (say) 300° would form no better recipient of heat than another of the same temperature brought from another part of the boiler.

“The inferiority in the heat-transmitting efficiency of boiler tubes as compared with surface-condenser tubes, appears to arise rather from the difference in the respective conditions under which the heat is presented to the metal. In the case of steam in the condenser, each particle may be said to collapse, on condensing, into perhaps but the $\frac{1}{2000}$ th or $\frac{1}{3000}$ th part of its volume a moment before, supposing, of course, the steam to have expanded below the atmosphere. This leaves a void into which a fresh particle is shot, with almost inconceivable rapidity (about 1,500 ft. per second), by the expansion of the remaining steam. The successive particles of steam thus arrive in turn, and with

almost lightning-like quickness, upon the condensing surfaces. In the case of the heated air and gases in the fire-box, however, they are in rapid flight from the fuel to and through the tubes. How far their heat is given off by radiation, and how far by convection, we have no means of knowing; but, in respect of convection, they cannot arrive successively upon the heating surface with anything like the quickness of steam in condensing. Even were a particle of hot gas to be at once cooled from $3,000^{\circ}$ down to 600° , it would be diminished to about one-sixth of its original volume, instead of $\frac{1}{2000}$ th or so, as in the case of steam, and other particles could not fully take its place until it had fallen by gravity, and against the resistance of a strong upward and onward draught, from its contact with the heating surface. We are not prepared to maintain that any system of mechanical agitation of the heated gases in the furnace would be practicable, and none, of course, could be permitted to interfere with the necessary rapidity of the draught. For every hundred-weight of coal fully burnt, upwards of 12,000 cubic feet of cold air are requisite, and this combined with the gases from the fuel, and expanded at a temperature of $2,500^{\circ}$ or $3,000^{\circ}$, would form a volume of from 60,000 to 75,000 cubic feet, the velocity of which can be measured from the openings through which it has to pass. In mentioning these very high temperatures we are bound to say that they are inferential, and have not been measured by a pyrometer; but even if we take $1,500^{\circ}$, the speed of the gaseous current through the furnace must be very great, and so must be the corresponding difficulty in the way of this current giving up its heat at once by convection.

“We may conclude, therefore, that the conditions under which the gases in boiler furnaces arrive at and give off their heat to the plates are mechanically disadvantageous, and that for this reason boiler plates and tubes transmit considerably less heat than they are really capable of doing. Without attempting to suggest the means, we may observe that could the hot gases be more rapidly brought into contact, particle by particle, with the heating surfaces, a less extent of heating surface would in all probability be required for a given rate of economical evaporation. A less extent of heating surface implies a boiler of less first cost and weight, and thus means for bringing each particle of the

furnace gases more quickly to the heating surfaces than at present would be commercially valuable."

11. *Patching Boilers.*—The following from the "Scientific American" will very suggestively close the present section:—"A serious accident which recently occurred to a steam boiler in England, shows what may happen when they are improperly repaired. The boiler in question was twenty-five years old, but had not been in use during the whole of that period. It was a plain cylinder boiler, 30 feet long, 9 feet diameter, and made of $\frac{3}{8}$ iron, in the usual manner, while the safety valve was loaded to a pressure of but 40 pounds to the square inch. This boiler gave way over the furnace, and was repaired there, by having a new sheet put in. Immediately after, the boiler exploded, killing one man and injuring five others. The seat of the rupture was at the junction of the old and new metals, tearing the old sheet through by the line of rivets. The direction of the break was in the length of the boiler for five feet, when the rupture developed transversely and tore the boiler into three pieces, one of which was thrown 200 yards from the original locality. Many persons would say that this is extraordinary, and instead of looking in the right direction seek to mystify themselves and others by elaborate theories, but the cause was plainly the weakening of the old plate by the strain imposed on it in putting in the new. It is not a little singular and significant, that while the inspectors in England who have charge of those excellent institutions for the prevention of steam boiler explosions, denounce the cylinder boiler in such terms as these: 'the recommendation is not given without good reason, that boilers of this treacherous, plain, cylindrical, externally-fired construction, should be discarded for those fired internally, which are much more reliable,' a few unthinking persons at the West are endeavouring to have tubular boilers rejected and these 'treacherous, plain, cylindrical, boilers' substituted instead."

SECTION SECOND.—APPLIANCES OF BOILERS AND THEIR PRACTICAL
MANAGEMENT.

12. The following, from the "Mechanics' Magazine," will very appropriately open this section:—"The alarming frequency

of boiler explosions, which are chiefly traceable to defective matters of detail about the steam generator, induces us to say a few words on the subject, notwithstanding that we have already many times sounded the note of warning on this head. But explosions so often arise from causes which are generally but little understood, and sometimes not believed in, that we think it only right to call attention to these most serious consequences when they arise from any special cause. Therefore, to enforce the lesson they teach, we will give one or two examples of recent catastrophes from badly constructed or unsound fittings, and other injudicious boiler arrangements. And we do this the more readily, knowing that it is possible for some defects to exist and yet to pass without notice until attention is specially called to them by an accident, perhaps of a fatal nature. But this state of things need not be. If a man is neither competent to judge of the safety of his own boiler, nor disposed to pay sufficient wage to secure this qualification in the attendant, there is still another course open. An occasional inspection by a qualified engineer would cost but little, while an occasional explosion of an unqualified boiler costs very much. After defective water-gauges, defective blow-out apparatuses perhaps stand next in order as being most frequently met with. This proves that the equipment of boilers in this respect is too often neglected, and suggests the expediency of a reference to the details of these defects. Three instances are specially noticed in a recent report of the Manchester Boiler Association, but these are only a few out of a considerable number which we might adduce. In one case the tap was of ordinary plug construction, but it had no washer or bolt at the bottom to retain the plug in its place, so that, if opened unawares when steam was up, the plug would have been blown out, and a dangerous rush of steam and water would have followed. Now the fault here is due to some extent to the make of the tap; in these common plug taps, open at the bottom, the bolt and washer are mostly out of sight, and too often out of reach. It is therefore difficult to ascertain whether the plug is secured or not, and so there is always a certain amount of risk attending their use. In a gland tap, with closed bottom, the gland is secured by bolts or nuts on the tap, which are more accessible and open to view, thus rendering these taps far preferable.

“The second case illustrated the danger of using taps constructed of two different metals. In this instance the plug was of brass, and the shell of cast iron; the tap on being opened stuck fast, and could not be closed again. This is by no means an unusual thing with taps of this construction; they frequently stick fast in this way, owing to the unequal expansion of the two metals. The use of such fittings should be discontinued, they should be made wholly of brass, have closed bottoms, and be fitted with glands. However much a blow-out tap may stick, force should not be used to start it, as the leverage on the elbow pipe is considerable, and the chances of fracture and consequent scalding very great. In the third instance, although the boiler had only been at work a few months, the waste or discharge pipe was so imperfect that on opening the blow-out valve such a rush of steam and water took place through the joint as drove the attendants from the boiler-room. As it was some time before the valves were shut down, there was, of course, considerable risk of the furnace crowns being injured. The danger of these defects is that the rush of water often renders it impossible to draw the fires, and as the supply of water is rapidly exhausted the furnace crowns are in imminent danger. Another case further illustrates the danger of not having boilers equipped with suitable mountings. The boiler in this instance was of the plain cylindrical externally fired class, 2 ft. 6 in. in diameter, and worked at a pressure of 80 lb. per square inch. No tap or valve was supplied for emptying or blowing out, but there was an unplugging apparatus. This consisted of a rod running perpendicularly through the boiler, passing through a stuffing-box at the top of the shell, and fitted into a tapered hole at the bottom. The rod was raised to empty the boiler, but to prevent it being raised too high a guard plate was secured over the top of it. The accident was caused by an unpractised hand assisting to blow out the boiler; instead of slacking the guard plate back a few inches the assistant removed it altogether. The result was that the steam pressure drove the rod up through the gland and blew it out. The gland struck the unfortunate man on the head, whilst steam and water from the opening poured upon him, and resulted in his death. This fitting, it is true, had been used for years with safety, but this was no excuse for its retention, inasmuch as it was evi-

dently of a character liable to produce accident. In fact it was no better than a dangerous trap to the unwary, which could not be used by any stranger to the boiler without danger to himself.

“The last instance we shall now notice—although we might multiply cases *ad infinitum*—refers to the unsuitable mounting of the manhole. The boiler here was situated at an ironworks; was heated by the flames from a couple of puddling furnaces, and was 30 ft. long, 4 ft. in diameter, and made of $\frac{3}{8}$ in. plates. The load upon the safety-valves was 45 lb. per square inch, although the pressure at the moment of explosion is said to have been only 38 lb. The crown of the steam-dome, which was 2 ft. 6 $\frac{1}{2}$ in. in diameter, perfectly flat, and made of 3-8 in. plates, was the only part which suffered from this rupture. In the centre of this crown was a manhole of oval shape, measuring 17 in. and 14 in. respectively in the major and minor axes. There was no mouthpiece to strengthen this manhole, and the joint was made by passing the cover inside the boiler and drawing it up to the plate by a couple of bolts, each suspended from an ordinary wrought-iron bridge. But this is a very unsatisfactory arrangement. The manhole should have been stiffened with a mouthpiece faced on the joint-surface. Where ordinary bridges bear upon the plate they must distress it, whilst there is a tendency to pull the manhole through the cover by the act of tightening up the bolts, and so to burst it open. This is just the action that took place in the explosion we are dealing with; the cover was forced through the manhole, and the crown-plate torn away from the remainder of the dome. The circle of rivets was rent completely round, from hole to hole, while the angle-iron to which it had been attached was comparatively uninjured. No weakness by corrosion or grooving could be detected; so that the unquestionable conclusion is that the rupture commenced at the manhole. Had this manhole been mounted in a suitable manner no such result would have accrued. The explosion was unattended by fatal results; but it illustrates very forcibly the danger of neglecting these matters of detail, which are too often looked upon as of only secondary or minor importance, whilst, in truth, they are of as much consequence as any other portion of the boiler.”

13. On the department of Boiler Mountings named in the last

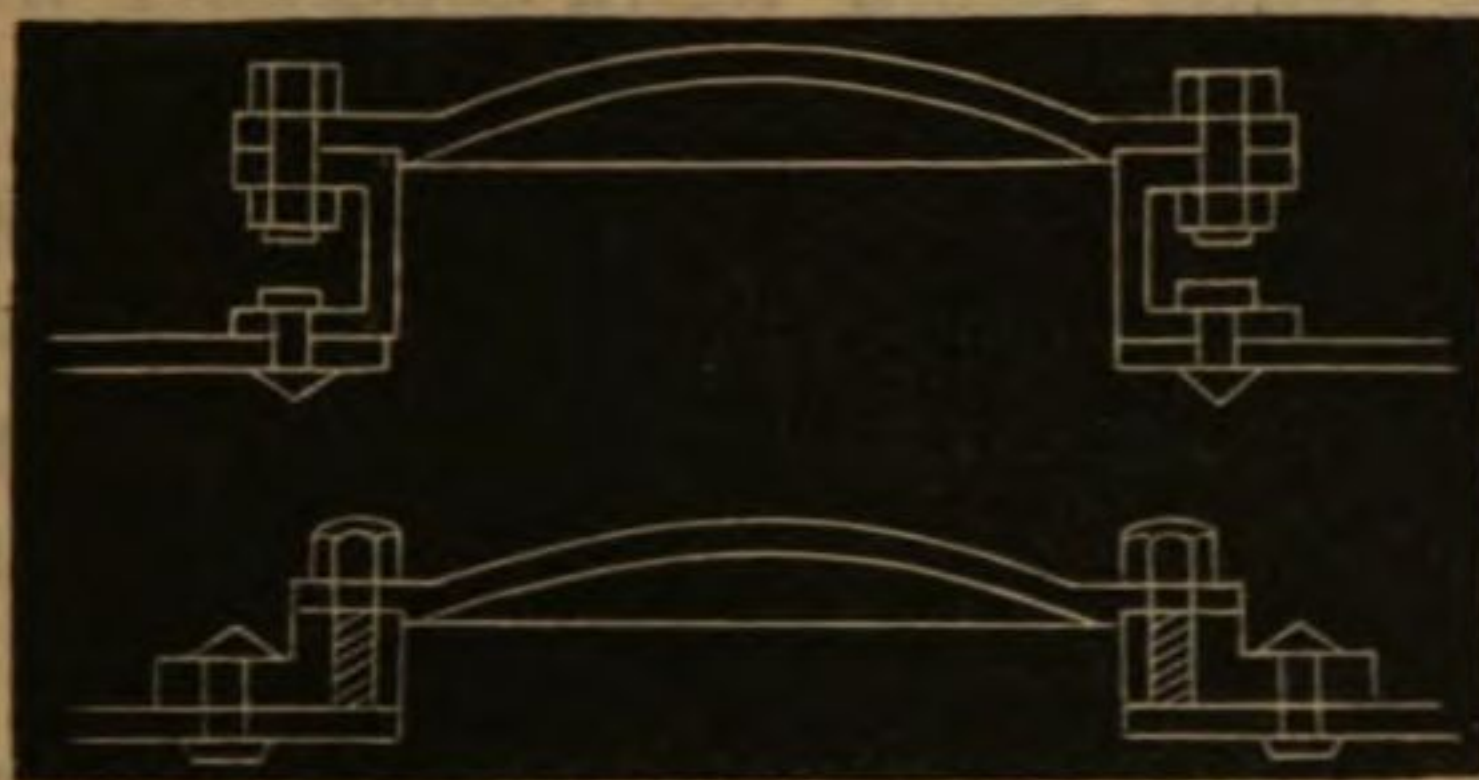
part of the preceding paragraph, namely, the *Manholes in Boilers*, we take the following from "Engineering:"—"A large manhole in a boiler renders the distribution of the strain upon those parts of the boiler plates which are in a line with it very unequal, the strain upon the plates at the edge of the manhole being greatly in excess of the average strain throughout their section. For this reason a manhole ought always to be strengthened by a ring riveted around it, so that the sectional area of metal at the point where the greatest strain is applied may be increased, and distortion be prevented by the thickening of the plate. When the manhole cover is, as is most frequently the case, of an oval form, applied to the inside of the boiler shell, and secured by crossbars and studs on the outside, it evidently of itself gives no support to the boiler. Indeed, in some cases the rupture of the plates has been assisted, if not produced, by the weakness of the manhole cover causing it to buckle and be drawn through the manhole by the combined effect of the pressure of the steam and the pull upon the crossbar bolts. To avoid this, the cover should be made of double plates, or of a plate of such a thickness that it can withstand the strain upon it without distortion. Whenever crossbars are employed to secure a manhole cover, their ends should not be allowed to rest directly upon the boiler plate, but upon a ring riveted around the manhole. The rivets by which the thickening ring is secured to the boiler should not be placed too near the edge of the manhole, as, if this is done, a great deal of the support given by the ring is counterbalanced by the loss of the metal taken away by the rivet holes from the place where it is most required.

"When a boiler is worked at a high pressure, a manhole cover with crossbar fastening should never be employed, and indeed, its use in any case is not to be recommended, its only advantage being the facility with which it can be removed. The best arrangements of manhole and cover for high pressure boilers are those shown by the accompanying illustrations, the cover being secured, according to one plan, by bolts passing through it and the flange of the manhole ring, and, according to the other, by studs screwed into the ring, which is made thick for the purpose of receiving them. In both arrangements the top of the manhole ring is made level, and it as well as the cover can thus

be faced in the lathe. Of the two plans we prefer that shown by the upper figure, as the bolts by which the cover is secured can be more easily renewed if broken, than the studs used in the other arrangement.

"The joint-flange of the manhole ring shown in the upper figure of fig. 11 may be conveniently made thicker than the rest

Fig. 11.



of the ring, either by forging the ring out of angle iron, having one thick web, or, if it is made out of a plain plate, by welding a thickening piece upon the flange after it is turned over. Very frequently the flanges of both manhole rings and steam domes are made too thin, and the springing which consequently takes place greatly increases the difficulty of obtaining a tight joint. The bolts employed are also, very generally, too small. We have ourselves always found it easier to make a good joint (if the flanges and covers are of the proper stiffness) with $\frac{7}{8}$ in. or 1 in. bolts, placed from 3 in. to 4 in. apart, according to the pressure, than with $\frac{3}{4}$ in. or $\frac{5}{8}$ in. bolts placed at correspondingly closer intervals. When the smaller-sized bolts are used, much trouble and annoyance is frequently caused by the breakages which take place when they are being screwed up. If the cover plates are made flat, they should be of a good thickness, so as to avoid springing. Thus, the cover of a manhole 15 in. in diameter should not be less than $\frac{3}{4}$ in. thick, if the boiler upon which it is fixed is worked at a pressure of 100 or 110 lb. per square inch. It is, however, better to give the cover the slightly arched form shown in the sketch."

13a. *Manhole Doors or Mouthpieces.*—Mr. Fletcher, the engineer to the "Manchester Association for the Prevention of Steam Boiler Explosions," has the following important remarks upon these appliances to boilers in his last monthly report (Nov. 1866):—

"The weakening effect of unguarded manholes is not produced solely by the amount of metal cut away, but to a great extent by the action of the covers. These are generally internal, and held up to their work by the pressure of steam, as well as by a couple of stout bolts and nuts, suspended from arched bridges; and as the surfaces of the plates at the joint are not dressed smooth, but left rough, a considerable strain is frequently put on the bolts to make the joints steam tight, especially when the cover does not fit the sweep of the boiler. Thus the action of the steam, combined with bolts, tends to force the cover through the manhole and split the boiler open. This is just the action that takes place. Nothing is easier than to strengthen these manholes. It is done in all modern boilers turned out by first-class makers, so that there is not anything novel about it. As, however, some of our members have old boilers to which this mounting is not attached, and which they are desirous of adding, while some makers continue to turn out new boilers without it—a practice from which so many fatal explosions, as just stated, have already occurred—it is thought that a description and sketch of this most simple but valuable mounting will not prove altogether unacceptable to our members, some of whom, indeed, have already requested it, and therefore it is now given.

"The manhole mouthpiece, represented in the accompanying sketch (not here given, see 'Engineering,' Nov. 23d, for the sketch), is an external one, made of cast-iron and in the shape of a short cylinder, with a flange both at the top and bottom, the lower one being curved, so as to fit the sweep of the boiler to which it is riveted, while the upper one is flat, and fitted with a cover secured with bolts and nuts. Both the cover and upper flange should be faced up true on their joint surfaces, while it adds a finish to the work to turn them up on the edge, as well as to face the cover on the outside for a width of about 4 in., so as to give a true bearing surface for the nuts. For convenience in lifting the cover, a wrought-iron eye-bolt should be attached to it at the centre. The height of the mouthpiece should be sufficient to admit of the introduction of the bolts between the flanges for securing the cover, while the opening should be large enough to afford a man easy access, say 15 in., which, however, is a liberal allowance, and might be slightly reduced in special cases, should

it be desirable to do so. The metal should be $1\frac{1}{4}$ in. thick for steam at a pressure of 60 lb., while the bolts should be 1 in. in diameter, and spaced about 6 in. apart. It is well to strengthen the upper flange by brackets, as shown in the cut; while the cover can be stiffened by ribs if required. By some makers the flanges are made as much as $1\frac{1}{2}$ in. thick. For steam considerably above 60 lb. on the square inch, mouthpieces are sometimes made of wrought iron, but those of cast-iron are found to work satisfactorily up to that pressure. No hemp ring will be required for making the cover joint, but merely a little red lead and oil. If the surfaces be properly got up, and provided that the lower flange be suitably riveted to the shell, little or no caulking will be required to make it steam tight. This external manhole mouthpiece is not the only form adopted. Some boilermakers prefer an internal one. Either of them, if properly made, works well."

14. As bearing closely upon the subjects discussed under the three last pars., and as also carrying with it suggestive hints on points too often lost sight of by boiler engineers, we take the following, under the title of "Manholes and Safety Valves" from the "Scientific American:"—"The Boiler Insurance Company, of Manchester, England, whose proceedings we so often notice, because they are doing a good work, have made a monthly report from which we extract certain parts of interest to our readers. In the course of certain investigations, in a recent catastrophe, they discovered that the seat of the disaster was the manhole. The boiler itself was quite a small affair, being only five feet and three inches high, two feet and four inches diameter, composed of plates one-fourth of an inch in thickness. The pressure carried was eighty pounds to the square inch, and the boiler was warranted for one hundred and fifty pounds. The boiler failed at the manhole, which was without any saddle or casting to strengthen it. The vents were three in number, diverging like cracks in a pane of glass, one running round a seam of rivets, and completely stripping off the external shell, which was blown into fragments. The jury, who were probably instructed before, had brought a verdict that the explosion was caused by the absence of the saddle plate or casting which is to be found on all properly-made boilers. The boiler in question was only six

months old. In addition to the bad construction of this boiler, as regards the omission alluded to, the jury called attention to the dangerous character of the safety valve. This was a small valve $1\frac{1}{8}$ inch in diameter, loaded by a spiral spring in such a manner that it was equal to a percussion cap in a charged shell, or in other words, was so utterly unreliable as to be worse than no valve, as will be seen from the following details:—The spring that held the valve was checked at the top by a yoke which passed over two standing bolts—one on each side of the seat. This yoke was secured by nuts, and no provision existed for regulating the tension of the spring so that the amount of pressure could be known. It was found that one turn of the nuts would increase the pressure from 80 to 150 pounds. Moreover, the spring was of so stubborn a character that at the point of blowing off, the steam barely wheezed through without raising the valve perceptibly. This valve, and the error of cutting a large hole in the boiler for the man-hole plate, was the cause of the 'accident.' We have repeatedly shown, by argument, by facts, and by illustration, that vague and unsound theories concerning boiler explosions are of no value whatever in ascertaining the cause. Men committed to certain views go prepared and indeed eager to find something in the accident to corroborate their assertions, and they generally succeed in so mystifying the matter, if called upon to testify in court, that neither they nor the jury have the slightest idea what they are talking about. But let a practical man go and look for evidences of weakness, for proofs that the boiler has been misused, or badly constructed, and he will find natural causes for the explosion. The safe load of a boiler plate, per square inch of section, has been ascertained; why then not take that as a starting point for investigation? Or, if this be proven correct, there are the many faults of construction, which tend to weaken a steam boiler, that practical men know exactly where to look for. One great trouble stands in the way of a full and impartial verdict in such cases. If a jury of practical men be impaneled, they are tradesmen themselves, and are naturally bound by trade ties to keep trade defects secret. If John Smith judges of his neighbour's boiler as he should, and condemns it because it was chisel-cut in caulking, because it was badly braced, because it was made of thinner iron than the laws

which govern the strength of materials demand, he knows not how soon his turn may come, and he be the prisoner at the bar instead of 'the intelligent jury.' It is, therefore, not at all strange that so many men of sound common sense, who say in private what they cannot say in a verdict, lend a willing ear to the voices of those who sing of ozone, of electric influences, of the decomposition of water, and other obsolete theories. It is not a matter of any man's 'opinion' how much pressure a boiler will stand. It is a question of the strength of materials. The plan of cutting a huge piece out of a boiler, without adding any protection to it, is manifestly an error that we believe is little practised in this country; and as for the safety valve, experience shows that the lever and weight is entirely reliable when properly made and cared for."

15. *Feed Arrangement for Internally Fired Boilers.*—It is scarcely possible to over-estimate the importance of attending to two things in the management of steam boilers, namely, to secure provisions for the supply of water; and second, for the proper escape of the surplus steam. Some points connected with these will be found in this and the succeeding paragraphs. In this paragraph attention is directed to the comparison drawn between the right and the wrong way of supplying boilers with water. The article in which these points are dilated upon we take from the "Practical Mechanics' Journal" (Nov. 1st, 1866), which is also illustrated by three valuable drawings for which we have not space, but for which we refer the reader to the Journal. "As so many injurious consequences are continually occurring either through defective apparatus, or the improper position of such apparatus for feeding boilers, we deem it of much importance to our readers to bring under their notice the arrangement and position of a very essential boiler appendage, as now recommended by the 'Association for the Prevention of Steam Boiler Explosions.'

"The recommendations of this Association on the points now to be considered have been thoroughly tested.

"In this arrangement the feed-box is fixed to the front end plate of the boiler, a little above the level of the furnace crowns, having attached to it a pipe passing into the inside of the boiler, and extending horizontally for about 15 feet, being blanked up at the end, and perforated with small holes for a distance of 5 feet from

the end. The feed-box may be fixed either at the right or left hand side of the front end plate, as may be found most convenient, but it is important that the horizontal internal pipe should be only a few inches below the surface of the water, and above the level of the furnace crowns.

“There are two main features in this arrangement. First, the position of the feed-box ; secondly, the delivery of the feed near to the surface of the water in the boiler, and above the level of the furnace crowns, by means of a horizontal internal perforated pipe. The advantages of these are as follows:—

“(1.) The position of the feed-box. It is very customary to fix the feed-box on the top of the boiler, where it is out of the immediate reach of the attendant when standing at his fires, and involves his climbing up to the top of the boiler to get at it. It is therefore much more convenient when placed at the front of the boiler. When, however, this is done, the feed-box is sometimes placed immediately on the level of the floor-plate, or only a few inches above it, when it is apt to be covered with ashes, and cannot be kept in clean condition. When placed, however, above the furnace crowns, as recommended, it leaves the firing-floor perfectly free, is out of the way of the ashes, can without difficulty be kept clean, and is more accessible for the attendant, who can hear the valve beat at every stroke, and regulate its lift at pleasure, without stooping or leaving his post in front of the glass gauges and furnaces.

“(2.) The delivery of the feed near to the surface of the water in the boiler, and above the level of the furnace crowns, by means of a horizontal internal perforated pipe. There are two serious objections to the very general plan of introducing the feed at the bottom of a boiler. First, it tends to contract the plates at the bottom of the boiler, and thus strains the transverse seams of rivets, very frequently rending the plates from rivet-hole to rivet-hole. This is less liable to occur when the feed is heated ; but though it may be brought up to a temperature even of 200°, yet the water in the boiler, with steam at a pressure of 50 or 60 lbs., would be 100° hotter. The delivery of the feed at the surface of the water by means of a perforated pipe meets this difficulty. The water enters in a shower, so that it does not impinge on any part locally, and before it reaches the bottom of the boiler is so

intermingled with the other water that it gains the same temperature, and thus does not strain the plates by unequal contraction.

"The second objection to introducing the feed at the bottom of a boiler is, that, in consequence of this, boilers are frequently drained almost empty when the fires are left banked up at night-time, in case of any derangement of the feed back-pressure valve, such as a piece of chip or dirt getting on to the seat, or the valve being worn so as not to be tight, &c. &c. From this cause frequent cases of injury to furnace crowns are met with. When the feed inlet is above the level of the furnace crowns, it cannot empty the boiler lower than its own level, and thus cannot lay the furnace crowns bare.

"The advantages of this arrangement, therefore, are—accessibility of the feed-box for keeping it clean, as well as for opening and closing the valve, &c.; also, the prevention of transverse seam-rending at the bottom of the shell, and a considerable reduction of the risk of laying bare furnace crowns at night times through leakage from the back-pressure valves.—V. D."

16. *Naylor's Compensating Safety Valve*.—Of this valve, which is being very extensively introduced in practice, Mr. G. Campbell read a description before the Leeds Association of Foremen Engineers, from which we take the following:—"There are certain qualifications which a good safety valve ought to possess, and the principal of which are—simplicity in construction, a free and sufficient exit for the steam; by this means we get one that will not allow the pressure in the boiler to exceed the weight on the valve. Further, a good valve should not be liable to be inoperative from sticking by friction, through pins and rubbing surfaces; and above all, if at all possible, beyond the reach of tampering with the weights by the hands of the ignorant, the malicious, or the reckless. The valve of Mr. W. Naylor, of London, possesses, in some degree, the qualifications recited; and before describing this arrangement, a section of which is shown in the illustration, we will look at it in comparison with the ordinary steelyard lever and stalk valve.

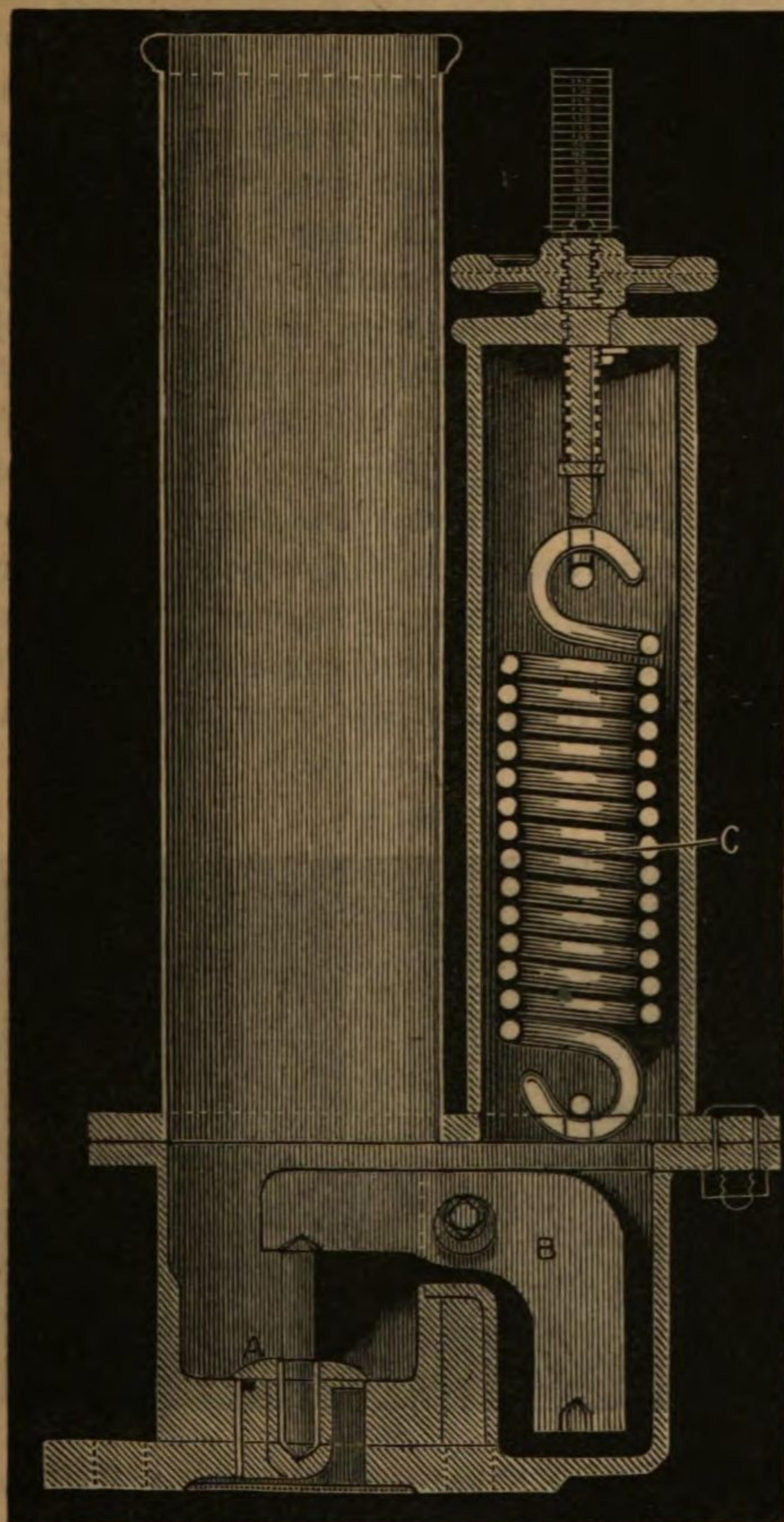
"Tredgold, in his able and valuable work on the steam engine, says, 'It would be a great improvement on safety valves if they could be so constructed as to be relieved of a part of their load

when raised from the seat.' Safety valves, as generally loaded with a spring balance, especially in the locomotive, portable, or other boilers subject to oscillation, instead of complying with Tredgold's sound observation, have a contrary effect when rising from their seat, increasing to a serious extent the load on the valve and strain on the boiler, which, no doubt, most of you have observed when looking at the valve blowing off, compared with the pressure shown on the pressure-gauge—a difference in excess, on the valve, of 20 pounds per square inch (sometimes more), being a common occurrence, if the fire under the boiler be urged, and the steam so generated not drawn off by any other medium than the safety valves.

"This can be easily shown by calculation. Take for example a valve 4 inches diameter, equal to an area of $12\frac{1}{2}$ square inches, consequently, the lever must be $12\frac{1}{2}$ to 1 for one pound on the end of the lever, to give one pound per square inch on the valve. Taking the angle of the valve-seat at 45° , it will be found that the end of the lever, where the spring balance is attached, must be raised half an inch to obtain an opening at the valve of $\cdot3551$ of a square inch, an opening not equal in area to a round hole $\frac{1}{4}$ 1ths of an inch in diameter. Then, if we take the graduated range of the spring balance at 30 pounds per inch, it will be clear that by raising the lever half an inch at its end (to obtain even the above small opening), an additional pressure of 15 pounds per square inch is put on the boiler by the tension on the spring balance; there is, beside this extra load by the balance, friction by the joint pins in the lever, and friction caused by the steam issuing through such a small opening. These, with the resistance of the atmosphere, have the effect in causing a great amount of needless pressure on the boiler, when the steam is blowing off strong at the safety valves. A theory has been advanced to account for the small rise of the valve from its seat, thus:—'That by the instantaneous reduction of steam pressure under the valve, so soon as an outward current has been established, motion takes the place of dead pressure; consequently, the pressure in the boiler sometimes rises dangerously above that to which the safety valve is loaded.' A valve has been designed to supply the defect pointed out by this theory, and shown in the Exhibition of 1862, by Mr. Bodmer, of London.

“We will now proceed to describe Mr. Naylor's arrangement of valves, and show how it obviates the increase of pressure by the rising of the valve for the escape of steam.

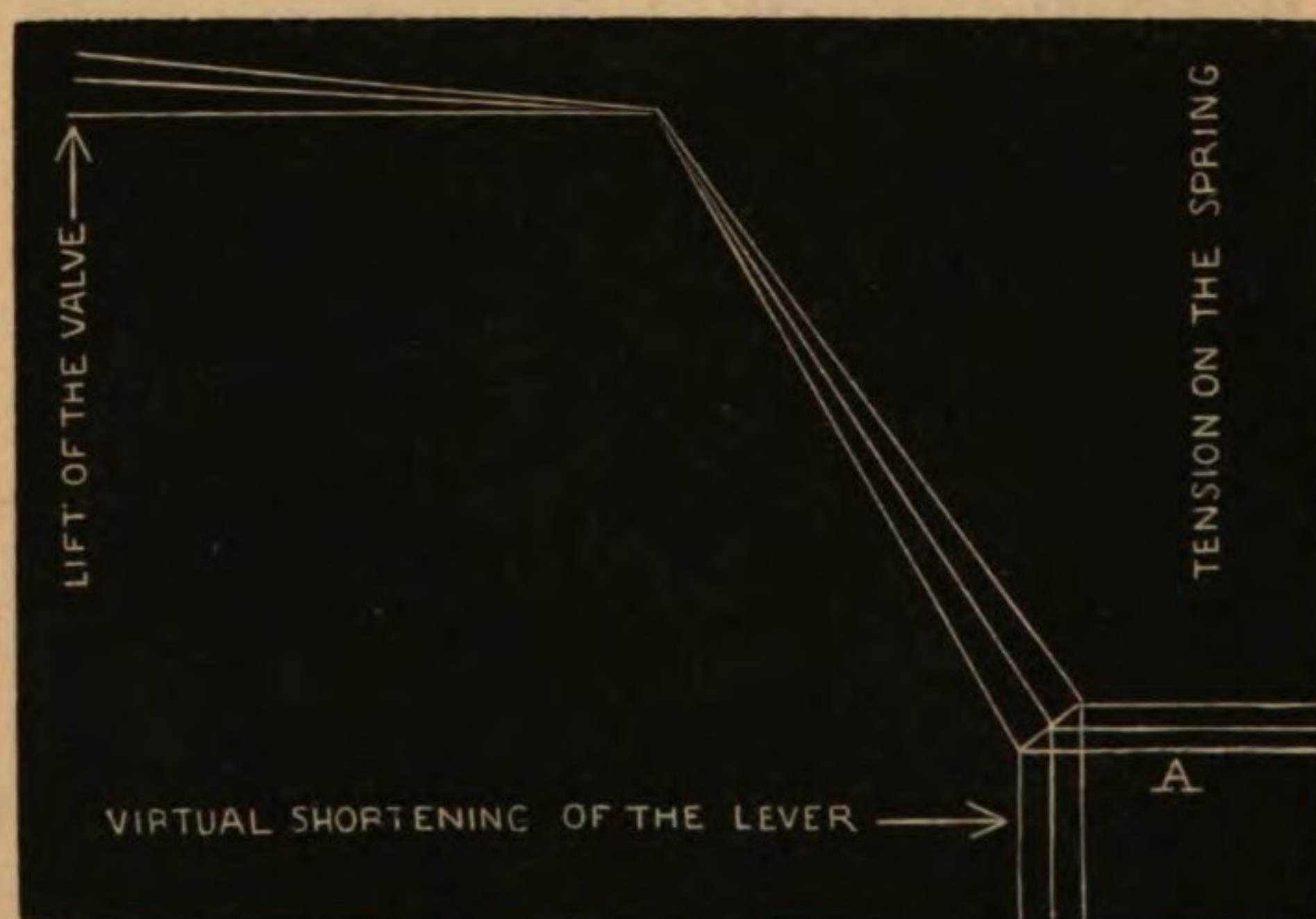
Fig. 12.



“By reference to figure 12, it will be seen that the valve A itself is of the ordinary kind, free in its seat, as shown, to pre-

vent binding. The lever B has one end bent downwards, and the spring C for loading the valve is attached to the lower end of the lever by a loop-link; it will be apparent that as the valve is lifted by the steam from its seat, that is, when the pressure inside the boiler exceeds the weight on the valve, the bent end of the lever moves inwards, or towards the valve, thereby virtually shortening its length, and relieving the weight on the valve, although the tension on the spring is increased by the same movement. This is the principal improvement over the ordinary form of lever, which, as we have seen, increases instead of diminishes the weight on the valve. The amount of relief given to the valve as it opens by this arrangement of lever, may be varied to any extent by the angle given to the lever and the range of tension on the spring. In the diagram of the lever, the lift of the valve, the tension on the spring, and the virtual shortening of the lever, are shown magnified six times. The thick lines show the dead position of the lever; the dotted lines show the movement of the lever at its half and full extent of travel. The horizontal lines to the right at A, Fig. 13, show the amount of tension put on the spring by the movement of the lever from its dead position,

Fig. 13.



to that of full travel; and the vertical lines at A show the virtual shortening of the lever by the same movement. The tension on the spring is taken at 600 pounds per inch, then when the bent end of the lever is at an angle of 55° with the horizon, and with a

tension of 1192 pounds on the spring, there will be a pressure of 170 pounds per square inch on the valve; but when, by the excessive pressure of steam, the valve has been lifted two degrees, or $\cdot043632$ of an inch, the spring has become loaded 36 pounds in excess, of the original tension, but to counteract this excess, the bent end of the lever has become virtually shortened $\cdot09$ of an inch, reducing its effective action on the valve, whereby the pressure on the valve is reduced from 170 to 168.4 pounds per square inch; this reduction of pressure will be apparent to all of you as a great improvement, opposed to what we saw done by the long lever and spring balance, when the valve is open for the escape of steam. The lift of the valve under consideration is taken at two degrees, the patentee having found, by experiment, that with his arrangement this is the average extent of lift for the escape of steam under ordinary circumstances. The lever and spring are enclosed in a box, out of reach of the person in charge of the engine or boiler, so that he is unable to overload the valve by holding down or hanging extra weight on the lever, but the person in charge of Mr. Naylor's valve can regulate the pressure by the nut wheel on the top of the spring box, drawing out, or putting tension on the spring until the maximum pressure at which he is allowed to work has been attained, when the shoulder on the screw attached to the head of the spring comes up to the underside of the spring box, rendering it impossible to increase the pressure by that means. Of course the attendant can at any time slacken or ease the pressure down to zero. The amount of pressure on the valve per square inch is shown by the index-plate on the side of the wheel, a pointer being fixed on the head of the screw as shown. Again, it will be seen that friction is reduced to the least possible amount by making all the bearing points of the steelyard, or knife-edged form. A spring, as the mode of weighting, may be objected to, from the fact that in consequence of the continual tension on it, in time it will deteriorate and be incorrect in its work. Of course this objection can be raised to 'Salter's spring balance,' as applied with the ordinary lever. Still this deterioration seems to be so slight that the spring holds its place as a mode of weighting safety-valve levers. Many of the valves on the locomotive stock of the London and North Western Railway are directly loaded by such a spring as is em-

ployed in this valve of Mr. Naylor's. Granting that the deterioration of the spring amounts to anything, it is at least on the side of safety, relieving instead of increasing the pressure on the boiler.

"With regard to the carrying-off power of this valve the patentee says, 'From experiments made upon different locomotive engines, generating as much steam as they were able when standing, with a coal fire and steam jet on in the chimney, he found that *one* of these safety valves, only two inches diameter, carried away the steam, and kept the surplus pressure down thirty pounds to the square inch less than *two* valves, each four inches diameter, loaded by long levers and spring balances, were capable of doing.' On one of the largest locomotive boilers in the country *two* safety valves, each four inches diameter, have been taken off, and *one* of Mr. Naylor's, only two inches diameter, substituted. The above fact requires no comment; it speaks strongly to the practical efficiency of the valve I have endeavoured to describe."

17. *Safety-Valve Levers*.—Under this head there is a practically valuable paper in "Engineering," which we here give—referring the reader to the Number for June 22d, 1866, for another article giving the principle upon which the rule for finding the position of centre of gravity of such levers is illustrated and described, which article we have not space for here:—"Amongst the many things," says the author of the paper, "requested from the editor of an engineering paper by his correspondents, there are few, if any, asked for more frequently than an explanation of the method of calculating the proportions of the lever and weight for a safety-valve. The frequency with which this request is proposed shows that the problem, simple though it is, is yet not understood by many of our readers, probably the junior ones; and for their benefit, therefore, we give the present article. The problem of ascertaining the relative proportions of the lever and weight for a given safety-valve, which is to blow off at a given pressure, usually presents itself in one of two forms. According to the first, the proportions of the lever are fixed upon, and the amount of the weight remains to be decided; whilst in the second the weight to be applied is settled, and the proportions of the lever have to be calculated. The former is the most simple problem, and it shall therefore be considered first.

“When the amount of the weight which, applied to a given lever, will load a given valve to a given pressure has to be calculated, the first thing to be done is to ascertain the weight of the valve itself and the pressure put upon it by the weight of the lever and its connexions. The weight of the valve itself can be readily found either by calculation or by simply weighing it, whilst the pressure due to the weight of the lever is best ascertained by attaching a spring balance to it at the point immediately over the centre of the valve, and, the lever being coupled to its fulcrum, noting the strain upon the spring balance required to lift the lever. The strain so found is then to be added to the weight of the valve, and the sum subtracted from the product obtained by multiplying the area of the valve (measured at the bottom of its conical seat) by the pressure of steam at which it is to work; the remainder will equal the load which the weight is required to place upon the valve. Next, the amount just obtained is to be multiplied by the distance from the centre of the valve to the fulcrum of the lever, and the product divided by the distance from the fulcrum to the point of the lever at which the weight is to be applied; the quotient will equal the required weight. We will illustrate the above rule by an example. Let the diameter of the valve at the bottom of its seat be 3 in., its weight is $1\frac{1}{2}$ lb., and the pressure at which it is to lift 60 lb. Let also the distance between the centre of the valve and the fulcrum of the lever be 3 in., and let the weight have to be applied at a point distant 20 in. from the fulcrum; and further, let the lever have been ascertained to exercise a pressure upon the valve of 40 lb. Then the area of the valve will be $3^2 \times .7854 = 7.068$ square inches, and the lifting power exercised by the steam will be $60 \times 7.068 = 424.08$ lb. From this is to be subtracted $1\frac{1}{2} + 40 = 41\frac{1}{2}$ lb. due to the weights of the valve and lever, thus leaving a lifting pressure of 382.58 lb. to be counteracted by the weight. Multiplying this by the length of the short arm, and dividing it by the length of the long arm of the lever, we get $\frac{382.58 \times 3}{20} = 57.387$ lb. as the weight required.

“The pressure exercised upon the valve by the weight of the lever itself, is equal to the weight of the lever multiplied by the

distance from its centre of gravity to the fulcrum, and divided by the distance from the fulcrum to the centre of the valve. As we have already stated, the amount of the pressure is best ascertained by means of a spring balance attached to the lever above the centre of the valve; but in some cases this method is not applicable, and it then becomes necessary to find out the pressure by calculation. When this is the case, the first thing to be done is to calculate the dead weight of the lever, and the next is to ascertain the position of the centre of gravity. The first of these two things is easily done, and the second is an equally simple matter, if very minute accuracy is not required. Generally speaking, a safty-valve lever is made parallel from the fulcrum to above the centre of the valve, or is made to deepen slightly towards that point, and it then decreases in depth towards the outer end at which the weight is applied. Sometimes also the thickness is diminished towards the outer end, and, when a spring balance is employed, an eye is formed at the extremity to accommodate the screw of the balance. This irregularity of form would render the *exact* determination of the position of the centre of the gravity a somewhat tedious operation; but its position can be very simply ascertained in a manner sufficiently near for all practical purposes in the following manner: if the lever is of uniform thickness, add together its depths at the fulcrum and outer end, and call this the sum of the depths; then the approximate distance of the centre of gravity of the lever from the fulcrum will be $= \frac{1}{3}$ length of lever $+ \frac{\frac{1}{3} \text{ length of lever} \times \text{least depth}}{\text{sum of depths}}$.

"If the lever is not of uniform thickness throughout its length, the depths multiplied by the thicknesses at the fulcrum and outer ends respectively, must be substituted for the simple depths used in the above rule; the remainder of the operation is the same as before. The above rules are founded upon the assumption that the lever tapers regularly from the fulcrum to the outer end. As we have already mentioned, this is not really the case, but practically the difference caused by the increase in the depth of the lever just above the valve is so nearly compensated for by the 'swell' or eye at the outer end for the screw of the spring balance, that the error in the position of the centre of gravity is very slight.

“The second form of the problem, in which the proportions of the lever required to put a given load upon a valve by means of a given weight have to be determined, is that which usually occurs in connexion with spring-loaded valves, as, for instance, those of locomotive engines. In such cases the pressure put upon the end of the lever by means of the spring-balance is generally equal to the load per square inch at which the valve is intended to work; and if the valve and lever were without weight, or were balanced, the proportions of the long and short arms of the lever would be as the area of the valve in square inches was to 1. It is, however, but rarely that the weights of the valve and lever are balanced, and they have, therefore, to enter into our calculations. The weight of the valve can be easily ascertained; but inasmuch as the proportions of the lever are unknown, its weight must be an assumed one. The assumed weight may be derived either from practical experience in similar cases, or it may be taken as being equal to the weight of the lever having the proportions which would be required if it were itself without weight.

“The method of procedure is then as follows:—Multiply the area of the valve in square inches by the working pressure per square inch, and from the product deduct the weight of the valve *plus* the pressure upon the valve, caused by a lever of the assumed weight; the remainder divided by the weight, or pressure of the spring, which is to be applied to the end of the lever, will give the leverage required. If the proportions of the lever thus obtained differ greatly from the assumed proportions, they may be employed as assumed proportions in a new calculation, and a nearer approach to accuracy thus obtained. We will illustrate this rule by an example, as in the previous instance. Let the diameter of the valve at the bottom of the seat be $3\frac{1}{2}$ in., thus having an area of 9.62 square inches; let also the pressure at which it is required to lift be 100 lb. per square inch, and let the weight or pressure of the spring to be applied to the end of the lever be also 100 lb. In such a case the pressure exerted upon the valve by the weight of the lever and its connexions would be about 56 lb., to which may be added 2 lb. for the weight of the valve itself, making 58 lb. to be deducted from the lifting pressure on the valve. The lifting pressure would be $9.62 \times 100 = 962$ lb.,

and deducting from this 58 lb., there remains 904 lb., which divided by 100 (the weight applied to the end of the lever) gives 9.04 to 1 as the proportions of the two arms of the lever, or, in other words, of the total length and the distance from the centre of the valve to the fulcrum. If the last-mentioned distance be $3\frac{1}{2}$ in., the total length of the lever will be $3.5 \times 9.04 = 31.64$ in. and so on.

“It should always be remembered that, whenever a portion of the load on a safety-valve is due to the weight of the lever, the load on the valve will not vary in the proportion of the weight applied to the end of the lever. Thus, in the example just given, 100 lb. at the end of the lever produced a load of 100 lb. per square inch on the valve; but 30 lb. at the end of the lever will give a load of more than 30 lb. per square inch on the valve, as a very simple calculation will show. Multiplying the 30 lb. by 9.04, the proportions of the lever, we get 271.2 as the pressure caused by it on the valve; and adding to this 58 lb. (due to the weight of the valve and lever), we get 329.2 lb. as the total pressure. This, divided by 9.62, the area of the valve in inches, gives 34.2 lb. per square inch upon the valve, caused by a weight of 30 lb. on the end of the lever. A very little reflection will show the reason of this. The effective weight of the lever and valve, 58 lb., of itself places a load of $\frac{58}{9.62} = 6.02$ lb. per square inch on the valve, and this load forms an increasing proportion of the total load, as the pressure at which the valve is to be worked is reduced, and therefore the amount of leverage required is diminished.

“When a valve is loaded by a lever and spring balance, and is to be worked at varying pressures, it is best to make the lever so that the proportions of its long and short arm are as the area of the valve, expressed in square inches, is to 1, and to allow for the weight of the valve, and the pressure caused by the weight of the lever by a special graduation of the spring balance. This special graduation is a very simple matter; it is only necessary to find the pressure per square inch on the valve caused by its own weight and the effective weight of the lever, and to make the scale of the balance lighter throughout by this amount. For instance, in our last example the weights of the lever and valve

were shown to produce a load of 6.02 lb. per square inch upon the latter ; in this case, the extension of the spring balance which would be produced by a load of 3.98 lb. should be marked 10 lb., that produced by a pull of 13.98 lb. should be marked 20 lb., and so on, the lever to be used with such a balance having its long and short arms in the proportion of 9.62 to 1. In America it is a usual practice to graduate the spring balances by the aid of a platform scale in the following manner :—A piece of plank is taken sufficiently long to extend across the platform of the scale, and allow of its being securely fastened down to the frame on each side. A kind of bridge is thus formed, into which the fulcrum of the safety-valve lever is screwed. The lever is then coupled to the fulcrum, the outer end extending beyond the scale, and the valve is also properly connected to the lever, the whole being arranged so that the valve bears upon the scale platform. The scale levers are next loaded with weights equivalent to the lifting pressure which will be exerted upon the under side of the valve by the steam, or, in other words, equal to the pressure per square inch at which the valve is to work multiplied by its area in square inches ; and by this means a lifting pressure of the amount desired is actually applied to the valve resting on the platform. The spring balance is then put in its place at the end of the lever, and, its lower end being secured to some fixed point, the nut is screwed down until the tension of the spring just balances the upward pressure exerted upon the valve. The position of the index of the balance then shows the proper point for the graduation, corresponding to the particular pressure to which the platform scale has been set, and by varying the weights applied to the scale any other points may be obtained, as desired. Messrs. Shand, Mason and Co. specially graduate all the safety-valve spring balances of their steam fire-engines. We have already explained their mode of effecting the graduation, in the course of a description of their steam fire-engines ; but we may repeat here that, when the boilers are being tested by water pressure, the safety-valves are at first screwed down to a much less pressure than that which is to be ultimately applied, the position of the index of the spring balance is then marked and the pressure at which the valves lift being noted by means of a Bourdon's gauge, the mark on the

spring balance is numbered accordingly. The spring balances are then screwed down further, and the operation repeated at a higher pressure, and so on until a sufficient number of marks are obtained."

18. *Superheating of Steam.*—Of late years a vast deal has been both written and said respecting the superheating of steam; and very diverse have been the opinions of engineers respecting its value, some indeed hesitating not to say that it has little practical value. From what will be found in the following extract from articles in the "Engineer," under dates Oct. 19th and Oct. 26th, it will be seen that the author is of opinion that we know comparatively little upon the subject. The importance, therefore, of an elaborately and carefully conducted experiment or series of experiments upon the effects of superheated steam cannot be sufficiently estimated. It is the aim of the author in the two articles above referred to, to detail the results and to examine the trustworthiness or otherwise of the conclusions drawn from them, of a series of experiments carried out by Mr. Isherwood, the Engineer-in-Chief to the United States Navy. Space does not permit us to give these articles in extenso, we are therefore compelled to give only a portion of them referring chiefly to a description of the apparatus employed. "Several years," says the writer, "have now elapsed since the value of superheating as a means of reducing the consumption of fuel required to produce a given power was recognised by engineers; yet, long as the time has been, and numerous as have been the experiments tried, those who have most to do with steam machinery are still most divided in opinion as to the exact value of superheating, the degree to which it should be carried, and the form of apparatus in which it should be effected. Much uncertainty, no doubt, has arisen from the very variable nature of the conditions under which the principle has been applied; from the want of any complete and well-digested record of the results obtained in practice by different firms who have adopted the principle; and from the ignorance which existed until a comparatively recent period as to the nature of superheated steam, and the true functions of a superheating apparatus. As regards our last proposition, it may be pointed out that neither Frost nor Dr. Haycraft appear to have comprehended the causes which led directly

to the great increase in volume which they obtained in the course of their experiments, by applying heat directly to saturated steam. They considered, indeed, that steam must obey laws totally different from those determining the behaviour of permanent gases when heated; and the fact that the somewhat extravagant anticipations which they formed were not fully realized, no doubt did much to retard the adoption of the principle by men practically engaged in the construction of steam machinery on an extended scale. We know now, of course, that steam obeys very nearly the same laws as the permanent gases, and that the enormous increase in volume obtained by some experimentalists, was mainly due to the evaporation of water contained in the saturated steam on which they experimented. But, however much our knowledge may have increased on this point, it is still undeniable that on many others we are very much in the dark. Of precise experiments, for example, to determine the true saving to be effected by superheating in any particular case, we have the records of few or none. We know, in a general way, that superheating steam saves fuel, and that is about all that is known precisely by engineers as a body. Under the circumstances, therefore, we think that some account of one of the most precise, refined, and minutely detailed experiments ever undertaken in connection with superheated steam, will prove interesting to our readers, and perhaps instructive.

“Next we have to consider the boiler and superheater. His description is excessively lengthy; with certain abridgments, however, we give it in almost the author’s precise words. The boiler is of the usual tubular type, with horizontal flues returned above the furnace and combustion chambers, and delivering the products of combustion into an up-take at the front end of the boiler. The up-take above the top of the boiler is enlarged into a cylinder 6ft. in diameter and 14ft. high, which contains the superheater, and is surrounded by the steam chimney or drum. The top of the up-take is drawn in to a diameter of 4ft. 8in., and on it rests the chimney of the same diameter. The shell is rectangular in form with the upper angles on all four sides rounded off. A water bottom extends beneath the entire boiler. The furnaces are five in number. They are 3.15ft. wide and 6ft. 7in. long; the bars are 6ft. long; height from top of furnace

to bottom of ash-pit, 3ft. 1½in. ; height from top of furnace to grate at front, 19in., at back, 27½in. ; width of water spaces, 4½in. including thickness of metal. Each furnace has a separate combustion chamber which delivers into the back up-take. The back smoke connection is separate for the two wing furnaces, and in common for the three central furnaces. It is rectangular in form, 22in. wide and 52in. high. The back up-takes for the wing furnaces are separated from that of the central furnaces by 2in. water spaces. The tubes are of iron, 90in. long and 2in. diameter outside. To each wing furnace there are sixty tubes, and to each of the central furnaces sixty-eight tubes. They are divided into seven rows vertically and forty-eight rows horizontally. The steam drum is in two portions, and surrounds the up-take above the top of the boiler. The lower portion is 10ft. in diameter and 7ft. high ; the upper portion 8ft. in diameter and 7ft. high ; the top of the drum is not less than 22ft. above the bottom of the boiler. The smoke stack is 32ft. high above the drum.

The superheater is composed of two cast-iron hollow rings, one of which is placed on the top of the cylindrical part of the up-take, and the other in the bottom. The exterior of the upper ring is divided into two equal compartments by partitions cast in. These rings are separated vertically by a distance of 11ft. 6in. in the clear, and they are connected by thirty-two wrought-iron 3in. tubes. The interior of the rings and tubes is in common ; the cross section of the exterior of the rings is an ellipsoid, formed by an arc of 4in. radius at top and bottom, and of 10in. radius at the sides ; thickness of metal 1in. ; inner diameter of ring, 4ft. On the bottom of the upper ring, and on the top of the lower, are cast projections 4½in. diameter, tapped to receive the ends of the tubes, which are screwed in. The tubes are distributed in two rows of sixteen each, those of the inner row being opposite the interspaces of those of the outer row. The tubes of each row are placed at equal distances apart. To avoid danger of fracture from expansion and contraction, each tube, instead of being entire, and so forming a rigid connection between the cast-iron rings, is in four parts, joined by cast-iron elbows tapped to receive the tube ends. Thus two of the four parts are vertical and two horizontal, the upper vertical parts being directly over the lower vertical parts ; the horizontal parts project inwardly

radially over the parts enclosed by the rings. The boiler steam entered one compartment of the upper ring of the superheater from the top of the steam chimney, the communication being guarded by a screw stop valve, A, 13in. diameter. It then descended through sixteen of the tubes to the interior of the lower ring of the superheater, whence it ascended through the remaining sixteen tubes to the other half of the upper ring, from which, through a branch pipe and a screw stop valve, B, it was delivered into the main steam pipe, where it mixed with the steam brought direct by that pipe from the top of the steam chimney. The pipe is 15in. in diameter, and in it, between the steam chimney and the point of junction of the branch pipe conveying the fully superheated steam, was placed an ordinary Buttery throttle valve C. By this arrangement the access of steam to the superheater could be either entirely prevented by closing the valves A and B, in which case the engine would work saturated steam, or limited to any desired extent by partially closing them. In a word, by using the valves as occasion required, either saturated steam or highly superheated steam, or any desired proportionate mixture of both, could be sent into the engine. We have been thus particular in our description in order to render the construction of the superheater perfectly clear. It will, we think, be admitted at once that such an enormous structure would be out of place in any ocean-going ship whatever, while its great height would alone suffice to preclude its use for naval purposes. As a superheater, regarded in the abstract, it was sufficiently good, and it does not appear that its use in a vessel like the *Georgianna*, carrying high deck-houses after the manner of all American river steamboats, was productive of inconvenience."

19. *Holt's Superheater*.—We take the following paragraph—illustrated in the original—from "Engineering," of date August 17th, 1866:—"We alluded in a paragraph last week to a form of superheater, which is being extensively applied by Mr. C. H. Holt, of Huddersfield, and now give an engraving of one of them as applied to a Cornish boiler. The superheater is placed opposite the end of the internal flue, and consists of a number of wrought-iron pipes, $\frac{5}{8}$ in. bore, bent into the form of a long U, and having their ends screwed into a casting set in the brick-

work at the top of the end flue. This casting consists of two horizontal Ω -shaped chambers placed side by side, the steam being led into one of them by a branch from the boiler, and passing thence through the U-shaped wrought-iron pipes to the other division of the casting, and thence to the engine. These U-shaped pipes are secured in the casting by screwed ends, and surrounded by short tubes, themselves screwed on the outside, and furnished with a nuthead, by means of which they can be screwed into the casting. As we mentioned last week, there are, amongst other places, now twelve of these superheaters at work at Saltaire, the steam being supplied from the boilers at 270° and superheated to from 500° to 600° , a temperature which is, however, reduced to 300° by the wiredrawing action of the throttle-valve before the steam reaches the engine. These superheaters are very simple, and appear to do their work well."

SECTION THIRD.—WEAR AND TEAR OF BOILERS—CAUSES WHICH
DETERIORATE THEM.

20. *On Incrustation in Marine Boilers.*—By far the most important paper of the year which comes under this section, was one read with the above title by Mr. P. Jensen, before the London society of Engineers, and which we deem right to give here *in extenso*:—"The question of keeping marine boilers free from deposit or incrustations has for many years been one of the most prominent before the profession—in fact, ever since the first steamer entered sea water—and it is still well worthy of our closest attention. It presents itself to us principally in three distinct forms, viz., safety against explosions, economy of fuel, and durability of the boiler itself. Now we all know that sea water causes incrustation and corrosion when boiled in a close vessel like a steam boiler. It is not, however, intended to enter into the question of internal corrosion of marine boilers, though closely connected with the subject before us, for fear of extending the length of this paper; but we may, in passing, note the fact that internal corrosion below the level of the water in a marine boiler does take place to some extent where the scale has been removed, but that otherwise this scale, so injurious when allowed to accumulate to any thickness, acts the part of a shield

or protector to the plates of the boiler against the action of certain salts contained in sea water, of which the muriate of magnesia is by far the most destructive, though happily small in quantity. And here the author may be allowed to call the attention of the meeting to an excellent paper 'On the Wear and Tear of Boilers,' read before the Society of Arts, April 26, 1865, by Mr. F. A. Paget, who treats the subject of corrosion of boilers very fully. In the ordinary practice of sea-going steamers with common condensers, the feed water is drawn from the hot well of the condenser, and thence forced into the boiler at some point or points near the bottom, and at a temperature of about 110 deg. Fah. The evaporation of steam leaves all, or sensibly all, saline or other extraneous matters contained in the water behind in the boiler, and, unless some means were adopted against it, we should, of course, soon get the boiler choked with incrustation or deposit. The means proposed or adopted for this purpose are many and varied, as will be seen in the sequel; but this much is certain, that any considerable thickness of scale allowed to accumulate renders the plates impervious to heat to a great extent, as this scale is a bad conductor. The heat generated in the furnace, and heating the plate next to it, cannot readily enough penetrate as far as the water, which, if in constant circulation, continually exposes fresh particles to the action of heat. The consequence is the overheating of the plates, and this to such an extent that holes may be burnt nearly through, leaving a sheet of iron the thickness of writing paper. That explosions do and must occur by thus weakening the plates, or by rents thus formed, is an established fact, and has for years formed the subject of many investigations and different theories, among which that called the percussive, first started and since completed by Mr. Zerah Colburn, seems the most natural, and has now probably become more generally adopted than any other. But even only partial explosions caused by rents or collapse of internal parts of the boiler have proved dangerous by scalding those that happened to be near at the time. The conducting power of wrought iron decreases with the temperature, so that at 400 deg. Fah. it has little more than half that at 32 deg. Fah.; how it stands with still higher temperatures we do not know as yet. If from some reason or other, such as the coating of the plate with incrustation,

which has sixteen times less conducting power than iron, the plate, with its covering of crust, should become heated to above 340 deg. Fah., then the water would exist on its surface in a spheroidal state, and thus only slowly and by the forcible ejection of it by colder water enable the heat contained in the plate to diffuse itself into the water; thus the plate would get hotter and hotter, and at last burn or oxidize where next to the fire. It is thus that plates are burned nearly through on account of incrustation. Important as is the question of the safety of the marine boiler against explosions, it cannot be denied that the economy of fuel, as regards marine boilers, has at all times, being a mere question of pounds, shillings, and pence, commanded, it is believed, as much attention as the consideration of human lives; witness the numerous patents, amounting to about one hundred and fifty, that have been taken out in this country for the prevention of incrustations and consequent loss in evaporative duty in marine boilers. Now this is not an occasion for speaking about the patent laws, or entering into the desirability of maintaining, altering, or abolishing the same; but as one argument in favour of maintaining them struck the author while preparing this paper, which has a direct bearing on this and most other engineering questions, it would be worth while to hear what the opponents of the patent laws have to say against it. The question is simply this:—How and where should we find such a complete record of the progress of engineering, inventive and progressive talent, but for the record of the Patent Office? In spite of all the nonsense that is patented, no doubt in sober earnest, still we find a vast amount of information in the specifications of patents. Would those that speak against patent laws like to do without patent specifications? To return to the subject. It has been said above that the scale has sixteen times less conducting power than iron. In an inquiry on incrustation of marine boilers by a Frenchman, M. Cousté, ('Annales des Mines,' 1854), a paper hardly noticed in this country till Mr. Robert Trefusis Mallet, in the 'Practical Mechanics' Journal, September, 1862, gave an extract of it, the following is stated:—That with marine boilers, starting quite clean inside, a loss of 8 per cent. or 10 per cent. of the evaporative duty of the fuel takes place after the first few days' work (a fact every marine engineer is aware of). At Bor-

deaux he found 15 per cent., and at Havre, after some days' constant work, he observed 40 per cent. In general practice, he says, it has been estimated that 40 per cent. of the heat of the fuel is lost by internal incrustation or deposit. He gives the following analysis of the incrustations of French ocean steamers:—

Stations.	Sulphate of Lime.	Carbonate of Magnesia.	Free Magnesia.	Iron and Aluminum.	Water.
Hamburg (deposit from the surface of boiler partly crystallised).	85.20	2.25	5.95	...	6.5
Mediterranean tubular boiler (amorphous).	84.94	2.34	7.66	.41	4.65
Mediterran. (amorphous deposit).	80.90	3.19	10.35	6.50	4.56

The water contained is believed to be mechanically present in the pores of the scale, and not chemically dissolved. Of course marine boilers are scaled as often as it can be done; but, for long voyages, it is often out of the question. Starting with 20 lb. pressure in the boiler, and clean fires, it is generally found that on the second or third day, in spite of greater exertions of the stokers and harder firing, only 19 lb. or less can be kept constantly, and this loss in efficiency goes on at an increasing rate. In eight days' constant steaming it has been found (in one instance) that, starting with 22 lb. pressure, the same was reduced to 15 lb. at the end of the voyage; this, it is supposed, without at all forcing the firing. Take another instance at random, the 'Persia' log, from year 1858, September 30 to October 9, inclusive:—Total number of nautical miles travelled, 2,886; total quantity of coals consumed, 1,402 tons. But whereas the consumption of coals per hour per indicated horse power was 3.95 on 30th September (she left New York on the 29th), it had increased to 4.314 on the 8th of October ('Artisan,' May, 1860). These few items illustrate sufficiently the well-known fact that incrus-

tation, even only as thick as paper, has a very great and perceptible influence tending to counteract the economy of fuel.

“As to durability, marine boilers, with all care, on an average only last five years; but this is chiefly owing to internal and external corrosion, rendered more intense by the salts contained in sea water, which, besides, promotes galvanic action in various ways. This must be understood to apply to boilers properly managed; that is to say, in such a way that only a very thin scale is allowed to be formed; for, as mentioned above, if thick scale is formed anywhere in places exposed to the heat of the furnace, or the escaping gases, this circumstance contributes directly to the burning away or oxidizing of the plates. This fact, that marine boilers wear out so quickly, must, as far as can be seen at present, remain unaltered so long as salt water is employed, and, in spite of repeated trials, and more or less success of surface condensing, in some instances, still we are far from the general introduction of surface condensing, and, considering the vast number of marine engines in existence worked with common injection condensers and salt water in the boilers, leaves the importance of the subject under consideration intact. It is now proposed to give a general explanation of the action of sea water as it obtains in the marine boiler. The specific gravity of sea water varies according to different localities; and calling that of pure distilled water 1,000, the average specific gravity of sea water, according to Farrady, is 1,027. For sea water of the specific gravity of 1,027.2 such as he used in his experiments, one cubic foot weighs 64.1416 lb., or 1026.265 oz. avoirdupois, and contains of

	oz.
Chloride of sodium, or common salt, . . .	25.762
Muriate of magnesia, . . .	3.282
Sulphate of magnesia, . . .	2.212
Sulphate of lime, . . .	1.013
Total, . . .	31.269

besides small quantities of other salts, but too minute to be of any consequence.

“Dr. Ure found the largest proportion of salt held in solution in the open sea to be 38 parts of 1,000, and the smallest 32; the Red sea, however, contains 43 parts in 1,000; the Baltic

contains 6·6; the Black sea, 21; the Arctic ocean 28·5; the British channel, 35·5; and the Mediterranean, 38.

“The following table shows the boiling point and specific gravity of water of different densities at a barometric height of 30in. of mercury:—

	Saltness.	Boiling point.	Specific gravity.
Pure water,	0	212°	1·000
Common salt water,.....	1-32nd	213·2	1·029
	2-32nd	214·4	1·058
	3-32nd	215·5	1·087
	4-32nd	216·7	1·116
	5-32nd	217·0	1·145
	6-32nd	219·1	1·174
	7-32nd	220·3	1·203
	8-32nd	221·5	1·232
	9-32nd	222·7	1·261
	10-32nd	223·8	1·290
	11-32nd	225·0	1·319
	12-32nd	226·1	1·348

“The deposit of salt begins at a density of 4-32nd, and at 12-32nd we have arrived at the point of saturation or the point at which water is incapable of dissolving any more. According to M. Cousté, an imperial gallon of water is capable of holding in solution at 60 deg. Fah. and at boiling point, viz., in the open air, the following weights nearly:—

	60 deg. Fah.	Boiling point.
Carbonate of lime,.....	Merely traces.	Merely traces.
Silica,.....	70 grains.	...
Sulphate of lime,.....	170 „	...
Carbonate of magnesia, 3·25 ounces.	...	...
Sulphate of potasium, 10 „	...	40 ounces.
Chloride of sodium,... 32 „	...	30 „
Chloride of magnesium, 266 „	...	580 „
Nitrate of lime,..... 500 „	...	580 „
Chloride of lime,..... 540 „	...	unlimited.

“The order of deposition in the boiler as the water becomes concentrated is,—1st, carbonate of lime; 2d, sulphate of lime; 3d, the salts of iron and oxides, and some of those of magnesia; 4th, the silica or alumina usually with more or less of organic matter; and 5th, chloride of sodium or common salt. Now it is well known that sulphate of lime is the worst of all the salts in a marine boiler. We have seen that 12-32nd, or 37 in 100, is

the point of saturation for common salt, but in the case of sea water, which contains other salts besides, 36 parts in 100 saturate at 226 deg., and 30 in 100 at 228 deg. Now, taking 20 lb. pressure, which is the most prevailing now, this with a saturation of 3-32nd to a rise of 1·2 deg. per 1-32nd, according to Professor Rankine, corresponds to a temperature of (say) 262·9 deg. Fah. How much salt can be held in solution at that temperature is not known to the author; but it is well known that the quantity decreases with increased temperature, and this is the reason of our not having yet arrived much beyond 20 lb. pressure in marine boilers working with salt water. In marine boilers we have chiefly to do with sulphate of lime, the proportion of the same so largely preponderating in the incrustation on analysis. As to carbonate of lime, this enemy to boilers is fortunately not a constituent of salt water, except in the Mediterranean, which contains a trace of it (·001 in 100 parts). Sulphate of lime forms deposits at all temperatures and all densities. Salt, on the contrary, forms deposits, as we have seen in the foregoing, not to any extent except when in the quantity of 3-32nd or 4-32nd, the quantity of the same required for saturation decreasing with increased temperature, and the amount of deposit that will take place long before the point of saturation having been arrived at, increasing with increased temperature or pressure. Sulphate of lime will deposit at any temperature; but it so happens that increase of temperature also increases the amount of deposit of this salt; for, according to M. Cousté, the solubility of sulphate of lime at different temperatures is as follows. The table indicates the solubility for different temperatures, as well as degrees of concentration at which the saturation of sulphate of lime takes place:—

Degrees of aerometer corresponding to the saturation.	Temperature.		Total pressure in atmospheres.	Solubility, or proportion of sulphate of lime in 100 parts of water at saturation.
	Fah.	Cels.		
12½	217·4	103·00	1	·500
12	218·84	103·80	1	·477
11	221·27	105·15	1	·432
10	227·48	108·60	1½	·395
9	231·8	111·00	1½	·355
8	235·76	113·20	1½	·310
7	240·44	115·80	1½	·277
6	245·3	118·50	1½	·226
5	250·	121·20	1½	·183
4	255·2	124·00	2	·140
3	261·68	127·60	2	·097
2	266·	130·00	2½	·060
1	271·94	133·30	2½	·023

“Now this table, and that of the amount of salt which can be held in solution at high pressures (say 20 lb.), a table, the author believes, not to be found anywhere, would give us as near as possible the quantity of water that ought to be blown out of a boiler to prevent, first, accumulation of chloride of sodium, and second, the deposition of sulphate of lime in any quantity injurious to the boiler in any high degree. True, there is one way of getting over the difficulty, viz., working with a lower pressure, but this is out of the question for several reasons, and we must hence use experience and experiments as our guide. From the foregoing, it will be clear that every pressure requires a different treatment, and a different amount of water to be blown off. If you blow off more than is necessary to prevent accumulation of salt in the boiler, you have to pump a greater quantity of feed water in, and consequently a greater amount of sulphate of lime in solution, which will be deposited as a hard tenacious scale. On the other hand, if you blow off too little, you will certainly get less sulphate of lime, but the accumulation of common salt will ultimately choke the passages in the boiler. This maxim, though true in theory, is modified in practice, because of disturbing elements, viz., the more or less rapid circulation of the water. To strike the just balance, it is, as before said, necessary to be guided by experience. It seems that ignorance has prevailed in

high quarters till very late years, because of want of data. Thus we find that Mr. James Napier read a paper in 1859 before the Institution of Engineers of Scotland, in which he recommended the use of a much larger generator (a sort of tubular feed water heater, the heat of the brine blown off being made use of for that purpose), and blowing off to a greater extent than generally used. He tried the experiment himself, and gave the results in a paper, read February 17, 1854, before the same institution. For the screw steamer 'Lancefield,' trading regularly between Glasgow and the Hebrides, he made a regenerator of ten times the usual surface, and blew off to such an extent as to keep the density of the water in the boiler at very nearly the same point as the water in the sea. After four weeks' running, the boiler was examined, and, instead of its being clean and free from scale, he found, to his surprise, it was coated with a much thicker scale than under usual circumstances, but soft, like newly-made mortar, but it dried and hardened before he could get it all out, and it was then nearly as difficult to scrape as the ordinary hard scale. On one voyage, when he was present himself, he gave the boiler as much feed as the pump would do, and he observed then that the water in the gauge glass was muddy. He continued the experiment for six months, but with lesser quantities of feed, and blew off till the tubes of the regenerator gave way, and then he discontinued. He saw then M. Cousté's paper, and the table contained in the same, which shows that at two atmospheres pressure sea water becomes saturated with sulphate of lime, even at the ordinary density, and as he loaded to 40 lb., and generally worked at about 30 lb., he saw at once the explanation of the phenomena. Although he blew off constantly from the surface by a conical tube, only some of the deposit of precipitate matter could be got rid of. This tallies exactly with the experience of some others. Some steamers in the American navy work with about or nearly 30 lb. pressure and salt water, but it is believed not with our ordinary tubular boiler, but with long cylindrical boilers having large round tubes and very ample water-way. In the discussion following, Mr. Elder said he had worked marine boilers with 30 lb. to 35 lb. and salt water. One naturally expected to find most deposit in that section of the boiler which contained most salt and lime, he said, but in a boiler divided

into eighteen parts (supposed to refer to his spiral flue high-pressure boiler), he found that though in the last section there was $2\frac{1}{2}$ times more salt in the water than in that of the first section, yet the deposit of lime was about equal in all parts. He concluded that the amount of deposit of lime depended on temperature, and not quantity of lime in it. The Americans, he said, ran with 40 lb. pressure, and did not appear to suffer from deposit, but they cleaned the boiler whenever they came into port. He found the deposit to be greatest where there was no current. He had observed boilers running with 45 lb. for three or four months, and there was not much more deposit than when working with 25 lb. He believed that there was a greater tendency for the lime to separate and deposit, but it did not necessarily settle down on the heating surface of the boiler.

"The 'Mechanics' Magazine,' in an article on 'Incrustation in Marine Boilers,' February 24, 1860, mentions Mr. James R. Napier's paper, and assumes, for want of better data, 28 parts of sulphate of lime to 1,000 of solution as the limit of saturation in boilers working at a pressure not exceeding 20 lb., and finds that with this assumption half the water must be discharged to keep the boiler clean, and this is affirmed by the practice of the British and North American Mail Company and others. Mr. Thomas Rowan found that when he had evaporated 2-10th and 4-10th of the water a trace of sulphate of lime deposited; 5-10th of the water sulphate of lime deposited in larger quantities; 6-10th of the water sulphate of lime decided, in larger quantities; 8-10th of the water sulphate of lime in very large quantities, also magnesia; and salt began to form. It is probable, therefore, that half or more of the water would have to be blown off in order to prevent formation of crust. This means that the density of the water should be kept at 2-32nd, for as sea water contains 1-32nd in its pure state, it is evident that half the water must be blown off to keep it at double its natural density. It may here be remarked that a density of 2-32nd is very generally kept in marine boilers, using about 20 lb. pressure of steam, and if this be constantly and carefully attended to, no considerable or deleterious thickness of scale accumulates, at least in places where the circulation is good.

"We come now to a brief survey of the various means pro-

posed, or adopted, for preventing incrustation. They consist in—

1. Surface condensers.

2. By heating the feed-water to such a temperature before entering the boiler as to oblige the sulphate of lime, and other salts, to accumulate in the heater only.

3. By introducing various substances into the feed-water before entering the boiler, the feed-water at the same time being subjected to heat so as to throw down the salts without allowing the same to enter the boiler.

4. By introducing various substances into the boiler so as to neutralize the effect of the salts, and,

5. By blowing off in the usual or various other ways.

1. Surface condensers. This seems at once to do away with the nuisance; the economy anticipated has not, however, been quite realized in practice. It has been found necessary to inject a little salt water along with the distilled water from the condenser, and the duration of the boiler has been found, in many cases, to be even shorter than with salt water, the reasons for which it is not thought necessary to enter into here.

2. Heating the feed-water, before entering the boiler, to such a degree that the salts are supposed to be thrown down in the heater instead of the boiler. This looks very feasible, but after all it amounts to shifting an evil from one place to another; let the heater be choked with salt and incrustation, and the engineer in charge has his hands as full as ever. To be admissible on board ship it must be compact, and at the same time accessible for thorough scaling, two conditions not very easily reconciled. The most practical shape is that of a casing with a number of dishes or shelves piled on the top of each other in the same, which can be taken out and replaced by clean ones in a short space of time. This plan has been patented by Mr. Spencer (No. 896), and in 1864 (No. 86), by M. L. E. E. Martin, a French gentleman. It is possible that this idea, by no means novel, possesses practical value, and at some future time may prove successful.

3. The plan of medicating the feed-water in a heater before it is admitted to the boiler, feasible and correct in principle as it appears, resolves itself, however, into a commercial question and is

contingent upon the price and bulk and other qualities of the substances proposed to be used for neutralizing the salts contained in the feed-water. Many substances have been proposed for this purpose, some evidently not of a harmless character as regards the iron plates of the heater, some evidently so expensive as to be out of the question, and only one or two are of a really feasible character. This latter class will be treated under the next head.

4. The plan of admitting foreign substances into the boiler to neutralize the salts, or some of them contained in the sea water, has found favour with a great many inventors; suffice it to say that nothing has appeared more likely in the eyes of practical and scientific gentlemen than soda. Mr. J. R. Napier has gone into an estimate of the commercial advantage of using soda ash for preventing incrustations. He assumes the boiler to work at 270 deg. = 26 lb. per square inch, and evaporating at that temperature $7\frac{1}{2}$ lb. water from 100 deg. per lb. of coal. The following is his table:—

	Mechanical method.	Chemical method.
Sea water supplied to boiler } at 100 deg.	15 lb.	8.33
Water discharged at 270 deg.	7.5 lb.	.83
Water evaporated	7.5 lb.	7.5
Total heat evaporating from:— 100 deg. at 270 deg. = 1092 × 5-10th ($T^1 32 - T^2 32$) = 1095	8215.5 deg.	8215.5 deg.
Heat discharged	1275 deg.	142 deg.
Fuel consumed in evaporation	1 lb.	1 lb.
Fuel consumed in prevent- ing crust	.155 lb. coal	{ .0172 lb. coal × .0085 lb. soda ash.
Total fuel	1.155 lb. coal	{ 1.017 lb. coal × .0085 lb. soda ash.

Thus, it seems, he says, that it requires only 172 lb. of coal + 85 lb. of soda ash containing 50 deg. of soda to be as efficient in preventing crust, as 1,550 lb. of coal alone, which evaporates $7\frac{1}{2}$ lb. of water from 100 deg. at 270 deg. And these methods are equally expensive when soda ash is 16.2 times dearer than

coal. This ratio varies with the efficiency of the fuel and the temperature of the evaporation. In this instance the loss by blowing off amounts to 14 per cent. Now there is no doubt that soda is a very good remedy against incrustations, and it has been repeatedly recommended by eminent chemists. Unfortunately even this remedy, so simple and efficacious as it has proved, has its drawback, and that of a very serious nature. In a German scientific periodical, 'Dingler's Journal,' volume 130, page 153, A. D. 1853, we find it mentioned that Professor R. Fresenius had recommended the use of a certain quantity of soda as a certain and cheap means for preventing incrustations where water is used that contains sulphate of lime (or plaster of Paris). He had used it for some months and with very good results. The factory boiler in question that formerly used to be scaled at proportionately short intervals now remained perfectly clean, and even patches of old incrustation too hard for removal had disappeared. But repeated trials and careful examinations had shown that a continued use of soda attacked the boiler plates very much. Dr. Zimmerman thought that all commercial soda contained more or less cyan, and that this is the reason of the corrosion of the plate; Dr. Rudolph Böttger, who mentions this fact in his 'Polytechnisches Notizblatt,' of 1853 (No. 20), says that he has made several experiments himself, according to which all commercial soda, even from the most respectable firms, contain cyan-natrium, and in consequence of this discovery he warns others against using it in boilers for the purpose of preventing incrustations. It is important to bear this fact in mind at a time when we find the chief inspector of the Manchester Boiler Association recommending the use of soda in steam boilers. Besides it must be remembered that such foreign bodies introduced in the boiler produce priming with all its evils.

5. Blowing off. The original practice at sea was, it is believed, to blow off from the bottom only, which was not found efficacious. Subsequently additional blowing off from the surface was resorted to, and this first at stated intervals and subsequently continuously. Thus we find Henry Maudslay and Joshua Field already in 1824 taking out a patent (No. 5,021) for withdrawing a fixed quantity of brine by meters of any kind; they preferred a pump with a loaded discharge valve drawing from the lowest part of the boiler.

They also in this patent mention a tubular regenerator for heating the feed-water by means of the heat of the brine drawn off. These brine pumps were at one time used to some extent, but have now been superseded by the surface blow-off system, because it was found that the pumps and the regenerator got choked with salt and thus became inefficient. Blowing off from the bottom has now become almost superseded by surface blowing off, because the latter plan has been found the more efficient of the two. The impurities contained in the sea water being, by the application of the heat of the furnace, brought out from the state of chemical solution into that of mechanical mixture in minute particles, floating about in the hot water and steam, are by the circulation of the steam and water floated to the surface in or along with the globules of steam rising to the surface, and there held in suspension in the bath of steam and water till accumulating to such an extent as to subside to the bottom; or, in their downward course adhering to the surfaces coming in their way. It is hence obvious enough why it has been found advantageous to catch these impurities before they can do any harm and blow them off. Intimately connected with the question of blowing off, is that of sediment collectors. Various sorts have been proposed for this purpose; but it is not proposed to enter into this subject, for the reason that, applicable as they might be for many other sorts of boilers, they are not so in the author's opinion as regards marine tubular boilers as now universally adopted, except in the shape of one or two common scum-pans, because any comprehensive system of pipes, pans, and vessels of any sort in the water room above the tubes would impede the free circulation of the ascending and descending currents, and thus probably do more harm than good. The author is, however, open to correction in these remarks, by practical men having actually tried such appliances. And this leads to the consideration of probably the most important element in the prevention of incrustation in marine boilers, viz., the influence that the construction of the boiler itself has upon the subject.

"If, as has been shown in the foregoing remarks, the sulphate of lime becomes all but insoluble in sea water at a pressure of 20 lb. per square inch above the atmosphere, such as is now commonly used in marine boilers, and if it is a fact, nevertheless,

that incrustation can be prevented in some boilers by means of proper and assiduous care, while no amount of care will prevent it in others, then we must arrive at the conclusion that the construction of the boiler, next to the proper and convenient means of constantly observing the state of the water and careful attention to it, forms the most important point in this inquiry. You may build marine boilers of very much the same general internal and external appearance to a superficial observer, and still one is a good and the other is a bad boiler to keep clean and to scale. It is obvious that it is only by the rapid and free circulation of the water and steam that we are enabled to work with salt water at all. It is further probable that, but for the circumstance that the circulation becomes more rapid as you increase the working pressure, and consequently the temperature, higher pressures than 20 lb., going even as high as 40 lb., have been found practicable with salt water. The chief principle to be aimed at seems this,—wherever the greatest heat is communicated to the plates there also ought to be the greatest facility given for a rapid circulation; and secondly, make the boiler accessible in all its internal parts, and especially in those most vital, viz., those in which scale, when formed, is most injurious and dangerous, which are those exposed to the greatest heat. The scanty room generally allotted to marine boilers makes it a difficult task for the designer to meet the above requirements without at the same time losing sight of other important considerations, such as economy and strength. The common multitubular marine boiler may be so designed—and this does not happen very often—that it may give little trouble to the engineer in charge to keep clean and scale it; the tubes must not be too close upon each other, and not too many rows in the vertical line; ample room must be left for a man to get in to clean the furnace crown, the back tube-plate, and the spaces between the tubes. The plan of inclining the back tube-plate somewhat, so as to allow the steam to escape more freely from the same, has found favour with many engineers, and has also collateral advantages. Of late years a multitubular boiler of another description, the vertical water-tube boiler, by Mr. Martin, a Chief Engineer of the United States Navy, has become extensively adopted in the United States Navy, and possesses, no doubt, advantages as regards scaling the tubes, the water being

in them, and the heated products of combustion passing outside and amongst them; this circumstance renders them more easily scaled inside with circular scrapers than is practicable with the tubes in our common marine boilers, that want scaling outside and never can be effectually scaled by mere mechanical means. The Field boiler, now well known amongst engineers, and because of the very rapid circulation in the tubes possessing the important advantage of keeping the tubes themselves, and also the tube-plate in which they are inserted free from scale, ought to do well for marine purposes one should think, although of course practice will answer that question. In American men-of-war, where they seem to be able to afford more boiler space than in the British navy, is often used a long circular return-tube boiler, the tubes being of large diameter (say 1 ft. or more), with very ample water spaces around and between them. They are, on account of their shape, capable of working with 30 lb. to 40 lb. per square inch almost without staying, and also to use salt water at high pressure. Many other boilers proposed or adopted for marine purposes might be mentioned, but it would be to travel beyond the subject to go into details of this question. To illustrate the importance that has at all times attached to this subject, the author here enumerated the more prominent patents that have been taken out in this country for preventing incrustation in boilers. Our limited space only enables us to note a few of the many propositions advanced.

“R. B. Lindsay, 1856 (No. 879).—Applies highly heated steam or air to cause the incrustation to crack, the boiler being cold at the commencement of the process. This method has been tried with great success in the Royal navy, and seems to offer great advantages wherever it can be applied.

“A. C., L. C., and J. L. Casartelli, 1856 (No. 2,623).—A salinometer consisting of two tubes, the ends of which are supported in two cocks. One cock is marked ‘blow,’ and the opposite one ‘limit;’ each tube contains a bead or float adjusted to certain gravities, that in the tube ‘blow’ being lightest. When density of water reaches the gravity of float in tube ‘blow,’ the same will rise in tube and indicate that more feed should be admitted, but the float in tube ‘limit’ will not rise till density exceed that of the other to a certain extent. When float in tube

'limit' rises, water should be fed in to prevent too great density. This instrument may also be used as a water-gauge. The above plan is not unlike Seaward's salinometer, patented many years ago.

"Mr. R. Armstrong, 1861 (No. 1,472).—His patent consists of a boiler with a vertical circular fire-box, with oval cross tubes, whose longest axes are horizontal in the centre and vertical at the end. He has also a plan for a feed-water heater consisting of a cast-iron cistern serving as foundation for boiler to stand on, and the heat radiating from the furnace heats the feed-water. This case is divided into two unequal parts by a partition across, reaching to within half an inch of cover or lid, which is to have a thick projecting convexity to dip at least one inch below surface of water when the larger part is fully charged with feed-water. The water expanding at the surface gradually passes over to top of partition to smaller part; the sediment settles in the larger part. He lines or lags inside of shell, with wooden staves, to prevent incrustation.

"Mr. R. Needham, 1861 (No. 3,285).—A longitudinal pipe at the bottom of boiler connected to a cock or valve outside. The pipe has at the bottom an aperture for entrance of mud and sediment, and at top a number of vertical pipes, each with ventilator-shaped funnel at water line, with mouth turning towards front of boiler, the flow of water being from the front to the back.

"Mr. G. Spencer, 1863 (No. 896).—On some convenient part of boiler in connection with the steam space a close vessel, furnished with a lot of diaphragms or dishes placed one over the other; through the centre or sides of each vessel he brings the feed-water pipe, so that it discharges into the top dish, from which it flows down from one to another through holes or spaces, with raised edges not quite so deep as raised edges round edge of dish. The whole interior is in contact with steam from the boiler. In addition, he coats the inside of the vessel and dishes and the inside of the boiler, with a suitable substance, such as Green's oxide paint, to prevent adhesion of deposited salts to the metal.

"After this brief notice of the more prominent patents, it is intended, in conclusion, to mention some of the well known constructions of salinometers; for if it be true, as seems to be the prevailing opinion among marine engineers, and as it has

been shown in the foregoing that after all we must depend more upon blowing off than anything else to prevent incrustation in marine boilers, then the salinometer deserves more than passing notice. One of the first in order of time is that invented twenty-six years ago by the late eminent engineer, Mr. Samuel Seaward. The instrument consisted of a strong glass tube, about $\frac{3}{4}$ in. bore and 14in. long, fixed at each end in a brass frame, to which are attached four cocks, one at each end and two at the side; by the two latter cocks the instrument is attached to the front of the boiler at such a height that the water in the boiler may fill the glass tube. On opening the two cocks attached to the boiler the water will rise from the bottom of the same by a pipe from the lower cock and fill the glass. On closing these cocks and opening the upper one two balls are dropped into the tube, the first ball being adjusted to one degree heavier than the water is intended to be maintained at in the boiler, the second ball one degree lighter; then close the upper cock, leaving the communication with the boiler open. Now if the density of the water should increase beyond the standard adopted the lower ball would rise, and if it should decrease the upper ball would sink. This is a very ingenious but rather delicate instrument, the use of which has now for many years been superseded by other contrivances. The simplest, through crudest, is one it is believed still extensively used in many places, and consists simply in a can or measure, sometimes detached from and sometimes attached to the boiler. This vessel is filled with water from the boiler, at certain intervals, for ascertaining the density; the water is allowed to cool down until a certain temperature is obtained and found by dipping a thermometer into it, and then the hydrometer graduated to that temperature is dipped in, which, by the degree of its immersion, indicates the specific gravity or density of the water. Such an instrument will, of course, fulfil the object of showing the density any time it may be required, but the operation is tedious and requires care, and handling such delicate glass instruments is not exactly the thing in rough weather, when the engineers have many parts of the machinery requiring their constant attention. The next step was the introduction of more practical and complete apparatus, the most commonly known of which is that called How's salinometer. . . .

How's salinometer case contains a separate compartment for the hydrometer and thermometer, and it is easy enough at any time to let in the water from the boiler so as to fill the case, shutting off the communication with the boiler, and blowing off the surplus water, if any; the density of the water when the ebullition has ceased can be read off. But this ebullition, resulting from the reduced pressure of the atmosphere to which the water in the salinometer case now becomes subjected, causes a quantity of hot water to be thrown out of the case, thus exposing the engineer to be scalded; the sudden rush of water from the boiler, if not properly checked by opening the cock very carefully, tends also to throw the hydrometer with great force upwards, causing the danger of breaking it; nevertheless, this instrument has been and is still extensively used.

"A more complete salinometer than the preceding one is the invention of Mr. Long, a chief engineer of the United States Navy. (The reader will find an illustration and description of this in p. 53 of our last year's volume). The objections to How's salinometer are obviated in this instrument by the addition of another separate tube. This latter contains a smaller internal tube by means of a cock communicating at the bottom with the water in the boiler while the top is closed, but having small openings near the upper extremity through which the water can escape in the outer compartment of the long tube or vessel, the steam at the same time freely disengaging itself. The long casing communicates at the bottom with the salinometer casing, which is fitted with a thermometer and a hydrometer. By this arrangement the rush of the water and the violent ebullitions are checked, and thus the density of the water can be observed without danger and inconvenience. But a more convenient and less cumbersome apparatus is represented by the salinometer, the invention of Mr. Gamble, chief engineer of the steamer 'City of Norwich,' has all the advantages of Long's, while the whole apparatus is contained in one piece, thus offering less obstruction, being more sightly, and taking up less space in the engine-room. This salinometer is now coming extensively into use, and is being manufactured by Messrs. Hayward, Tyler, & Co., of Whitecross street.

"The water is admitted, through the side entrance of the

fourway cock into the hollow of that cock, and from there, by opening the regulating screw of the jamb valve, into the bent copper tube in the salinometer case. At the top of the bend is a hole for letting the steam freely escape. By passing through in this way the force of the water is broken, and it will now enter the larger tube containing the hydrometer quietly. That tube is cut open on one side, and a corresponding hole left in the casing, with a glass plate inserted in the same, shows the density of the water at any time. By the side of the hydrometer tube is a cavity containing the thermometer, the indications of which can likewise be seen through a glass. An overflow pipe carries the surplus water away. Closing the jamb valve occasionally, and then blowing through from the boiler, enables the engineer to clear the supply pipe from any sediment, and this is an important point. The next operation on starting the salinometer afresh is to blow it through, which can be easily done by opening the jamb valve and setting the handle of the fourway cock so that a line on the dial-plate points straight through from the salinometer to the waste pipe; this clears the salinometer, and allows the water in the supply pipe time to cool down before entering the salinometer; 200 deg. Fah. is the temperature the hydrometer is gauged to. By the regulating screw of the jamb valve this can be easily and conveniently obtained as well as retained. Another great advantage in this practical little instrument, though it may not at first sight appear to amount to much, is the arrangement of the scales. The indications are given outside the brass face of the instrument where they can be read off instantly. In conclusion, there is no doubt that, after all, blowing off in the proper manner is the best means of preserving the boiler, that there cannot be given the engineer facility enough to do so, and that a salinometer possessing the advantages just described, which are fully borne out in practice, forms the best safeguard against the incrustation of marine boilers."

22. *Means for Preventing Boiler Incrustations and Corrosions.* From a paper in the "Scientific American," by Professor Chandler, we take the following :—"Numberless substances and methods have been proposed, from time to time, for preventing the bad effects of impure water in boilers. Although it is beyond the plan of this report to discuss, or even to mention them all, it is

important that some general idea of the principles upon which their supposed efficacy is based be given here.

Most of the methods are designed merely to prevent and remove incrustations; the opinion has been already advanced, however, that corrosion is much aggravated by the presence in the boiler of calcareous deposits. Methods which prevent incrustations must therefore diminish corrosion. Some of the methods to be mentioned are applied to the water before it enters the boiler; in other cases, substances are introduced into the boiler itself. In most cases, the salts of lime and magnesia are either precipitated in fine particles as a loose mud, or rendered permanently soluble.

Filtration, which removes suspended impurities, is in this case useless, as the salts to be removed are in solution.

Distillation is particularly recommended, and employed to a considerable extent, for marine boilers using sea water. The anomalous behaviour of distilled water has been already mentioned. This method of purification is entirely impracticable for locomotives.

Boiling expels the free carbonic acid, and causes the separation of the carbonates of lime and magnesia, and if conducted at a high temperature, under considerable pressure, results in the almost complete precipitation of the sulphate of lime. This would, however, merely transfer the incrustations from the locomotive boiler to some other vessel, and would, therefore, be valueless in this case.

Lime water is employed on a large scale at Woolwich. The lime combines with the free carbonic acid, causing the precipitation of the carbonates of lime and magnesia. The proportion of lime water added varies with the amount of free carbonic acid present. In a few hours the carbonates settle, leaving the supernatant water clear. As the lime added is also deposited as carbonate, nothing is introduced which remains in solution. The sulphate of lime is not affected. This method is readily applied and inexpensive. It merely requires extra tanks for the lime water, and for settling the sediments. It is specially applicable to water containing little sulphate of lime.

Baryta water, which affects the sulphate, as well as the carbonates, has been proposed, but its high price puts it entirely out of the question.

Carbonate of Soda.—This salt precipitates the carbonates of lime and magnesia, by withdrawing the free carbonic acid. It also decomposes the sulphate of lime, forming carbonate of lime, which it deposited, and sulphate of soda, which remains in solution. This is very effective, and not expensive. Added in excess, however, it is said to produce priming and leakage. Carbonate of potash would answer the same purpose, but is more expensive; caustic soda and potash behave in nearly the same manner. Carbonate of ammonia has the same effect on lime salts; but does not precipitate the magnesia. Carbonate of soda is preferable to the other substances of this class on account of its low price.

It may be advisable to employ caustic soda in some cases, on account of its superior efficacy in loosening hard scales.

Chloride of Barium—Decomposes sulphate of lime, forming sulphate of baryta, which is deposited. This would be too expensive in this country, besides being objectionable on account of the chloride of calcium left in the water. Hydrochloric acid is sometimes added with the chloride of barium to dissolve the carbonates of lime and magnesia, and form the soluble chlorides of calcium and magnesium. In excess this acid would attack the boiler plates.

Carbonate of Baryta—Decomposes sulphate of lime, with the formation of sulphate of baryta and carbonate of lime, both of which separate as a deposit. The carbonates of lime and magnesia contained in the water are not affected. This method may be applied to water which has been freed from its carbonates by lime water, the carbonate of baryta being introduced into the boiler. Carbonate of lead, which behaves in a similar manner, has been suggested for the same purpose; larger quantities would, however, be required, and is much more expensive.

Chloride of Ammonium.—This salt is very effective in decomposing the lime and magnesia salts, even after they have been deposited, forming soluble chlorides of calcium and magnesium, carbonate of ammonia, which is rapidly expelled with the steam, and sulphate of ammonia, which remains in solution. The quantity added should, at least, equal the quantity of carbonates of lime and magnesia and sulphate of lime present in solution.

When it is desired to loosen a considerable deposit, hydro-

chloric acid may be cautiously added at the same time. The acetate and nitrate of ammonia resemble the chloride in their action, but are neither as powerful, nor as low priced.

Chloride of Tin—Has been used by a French engineer. He employed about eight pounds per week for an engine working twelve hours daily. He recommends for large boilers one pound of the salt for every sixteen cubic feet of water. The chloride of tin is decomposed, forming an insoluble basic salt which is deposited, and a soluble acid salt which dissolves the lime and magnesia sediments.

It is not equal to chloride of ammonium in effectiveness, and is far too expensive for general use.

Silicate of Soda, Phosphate of Soda, Arseniate of Soda, etc.—Have been recommended for purifying water for special purposes, as for tanning and dyeing. They are not at all applicable in the present case.

Hyposulphite of Soda—Has been proposed on account of its property of increasing the solubility of sulphate of lime. It would be too expensive in practice.

Catechu, Nutgalls, Oak Bark, Shavings and Sawdust, Tan Bark, Tormentilla Root, Mahogany, Logwood, etc.—These substances all contain more or less tannic acid, associated with soluble extractive and colouring matters. When they are introduced into the boiler, the soluble constituents are dissolved by the water, and basic tannate of lime is formed, which separates as a loose deposit, which does not adhere to the sides of the boiler. It is preferable to use the aqueous extract, as sawdust, chips, etc., are liable to find their way into the cocks and tubes, although they act mechanically, receiving incrustations, which would otherwise fasten themselves on the sides of the boiler. In selecting one of these substances, one would endeavour to secure the largest quantity of tannic acid and soluble extractive matter for the lowest price. Some of these substances are said to be very effective, one-half pound of catechu being sufficient for 100 cubic feet of water. From 4 to 6 pounds of oak chips have been recommended per horse power, or a half bushel mahogany chips for every 10 horse-power.

Potatoes, Starch, Bran, Linseed Meal, Gum, Dextrin, Irish Moss, Slippery Elm, Marshmallow Root, Glue, etc.—These sub-

stances form, sooner or later, a slimy liquid in the boiler, which prevents more or less completely the settling and hardening of the deposits. Some of them may even hold the lime and magnesia in solution. Potatoes have been used for many years, wherever steam engines are employed; half a peck or a peck are thrown into the boiler weekly. Linseed meal mixed with chopped straw was employed on a German railway, a peck at a time being introduced into each boiler. Some writers object to these organic substances, on the ground that they are liable to cause frothing.

Sugar, Molasses, Corn or Potato Syrup.—Both cane and grape sugar form soluble compounds with lime salts, and consequently prevent their separation as incrustations. One engineer found that ten pounds of brown sugar protected his boiler for two months; another, that six pounds of corn starch syrup had a similar effect. Another used molasses with success, introducing a gallon at a time.

Fatty Substances.—One writer used whale oil to prevent incrustations, two or three gallons at a time. Others smear the inside of the boiler with various mixtures of a fatty character. Stearine, mixed with wood ashes, charcoal and tar, has been recommended, or tallow, with soap and charcoal diluted with oil or tar, or tallow and graphite. This plan could not well be applied to a locomotive boiler with its numerous tubes, even though it should prove effective in cylinder boilers.

Tar, Pitch and Rosin—Have been applied in a similar manner.

Mechanical Agents—Of various kinds have been employed with doubtful success to prevent the hardening of deposits on the sides of the boilers. By offering solid particles suspended in the water, they serve as nuclei for the accumulation of the calcareous sediments. Clay was formerly used. It was carefully sifted and washed, and introduced, five or six pounds at a time, into the boiler. It was found, however, that hard silicious particles were sure to find their way to the cylinder, scratching its surface.

Sawdust, Chips, Shavings, Straw, Powdered Glass, Scraps of Sheet Iron and Wire Gauze—Have also been used and generally abandoned.

A Wire Gauze Lining—Has been proposed, and I believe, patented, as a protection against incrustations. Such an arrangement may perhaps be useful in a cylinder boiler, but could not well be applied to the tubular boilers of locomotives.

Blowing Off.—The frequent blowing off of small quantities of water, say a few gallons at a time, is undoubtedly one of the most effective and simple methods for removing sediments and preventing their hardening on the sides of the boiler.

The water entering the boiler should be directed in such a way as to sweep the loose particles toward the blow-off cocks, that when these are open they may be carried out with the water. This blowing off should take place at least two or three times daily, perhaps much oftener.

Great care should be taken to avoid emptying the boiler while there is still fire enough to bake the muddy deposits.

Washing out frequently is very efficacious.

Metallic zinc, attached to the plates of the boiler so as to secure actual contact, is probably one of the best preventives of corrosion. As already mentioned, the iron protects the copper and brass tubes by rendering them electro-negative, being itself much more rapidly corroded in consequence. Zinc bears the same relation to iron that iron does to copper, and may be made therefore to bear the corrosion. Rolled zinc is preferable to slabs, as the latter are very crystalline, and are consequently very unevenly corroded, soon becoming brittle and working loose.

Electro-magnetic inductors have been proposed. One has been patented by Parry, and another, I believe, by A. F. Porter. It is claimed that these inventions prevent corrosion and incrustations, though I have seen no evidence either in their favour or against them, nor do I know their principle.

G. F. Bonsfield's patent for protecting iron from wear by galvanic action, dated Feb. 19, 1862, consists in insulating electro-negative bodies, copper, etc., by washers or packing of india-rubber, or other non-conducting substances. I know nothing of its merits.

Incrustation powders, bearing generally the names of their proprietors, are extensively advertised and sold; they are either worthless or are sold at such extravagant prices as to make their use extremely ill-advised. I have examined several of them.

Those which are at all valuable consist of one or more of the substances already mentioned, and the only novel result of their use is the payment of many times the commercial value for a fair article.

One which is put up in tin boxes, containing about one pound, at \$2 50 each, contains—

Carbonate of lime,	.	.	.	95.35
Carbonate of magnesia,	.	.	.	0.67
Oxide of iron,	.	.	.	4.15
				100.017

It differs little from some of the incrustations in composition, and is of no value whatever.

Another contains—

Logwood,	.	.	.	75.00
Chloride of ammonia,	.	.	.	15.00
Chloride of barium,	.	.	.	10.00
				100.000

This is a very good article, but at the price for which it is sold it cannot be used in quantities sufficient to produce much effect. In fact, chloride of barium is too expensive to be used in this country at all.

In conclusion, I would advise—

1. The use of the purest waters that can be obtained, rain water wherever possible.

2. Frequent use of the blow-off cock.

3. That the boilers never be emptied while there is fire enough to harden the deposit.

4. Frequent washing out.

5. Experiments on the efficacy of zinc, lime water, carbonate of soda, carbonate of baryta, chloride of ammonium, some substance containing tannic acid, linseed meal, and the electro-magnetic inductor."

23. *Zinc Plates for Preserving Boilers from Corrosion.*—

"The statement seems incredible, that for forty-two years science has been in possession of cheap and simple means for completely protecting steam boilers from rust, and yet these means have never been made use of in the arts. The great Collins steamer *Baltic*

is now lying in the East river, and on the wharf by her side is an enormous pile of iron rust, that formerly made up the tubes and tube sheets of her boilers. These boilers cost many thousands of dollars, and their condition is similar to that of hundreds of other boilers in this and other countries. Can it be that a few plates of zinc soldered to these boilers would have preserved them entirely from this decay? There is every reason, short of extensive practical trial, to suppose that they would.

In the year 1824, Sir Humphrey Davy announced his discovery that if a metal which is corroded in salt water is placed in contact with a second metal that is more easily corroded, the action is confined to the second metal, and the first is perfectly preserved. This principle is not limited to the action of salt water, but holds in regard to all corrosive fluids; the most easily corroded metal is called the positive, and the protected one the negative.

Sir Humphrey Davy proposed to protect the copper sheeting of ships from corrosion by attaching to it pieces of zinc, but the plan did not prove a practical success. It has been generally understood that the cause of the failure was the perfection with which the copper was preserved—it was said that the copper was kept so bright that barnacles adhered to it, a slight coating of the poisonous oxide of copper being supposed necessary to drive these shell fish away. M. Becquerel says that this impression of Davy's was erroneous, that neither barnacles nor seaweed adhere to bright copper, but that the real cause of the failure of Davy's process was the erroneous theory adopted by its author. Davy supposed that the mere contact of the two metals was sufficient, while the fact is, the protection is due to the chemical action going on between the more easily corroded metal and the liquid. A coating of oxide or other salt soon forms on the surface of this metal, and stops the action, when the protection ceases. To continue the protection, therefore, it is necessary that this coating should be constantly, or frequently, removed.

There is a limit to the area of iron surface which a piece of zinc will protect, though it is very large. A few small pieces of zinc would probably protect the largest boiler; they should be soldered to the iron, and should be so situated that their surfaces could be frequently scoured or scraped."—*Scientific American*.

24. On the Corrosion (*a*), and the Testing (*b*), of Locomotive Boilers, we take the following paragraphs from "Engineering," (May 11th).

(*a*.) "At the meeting of the Mechanical Engineers held at Birmingham on the 3d inst., a paper was read by Mr. William Kirtley, of Derby, 'On the Corrosion of Locomotive Boilers, and the Means of Prevention.' Mr. Kirtley alluded to the corrosion which occurs in boilers made with lapped joints, and attributed the grooving action which takes place, to the fact that neither the plates themselves nor their attachments to the firebox and smokebox are in the direct line of the strain that is put upon them by the pressure of the steam. The furrowing action is most marked at the interior of the smokebox end of the barrel, where it occurs most frequently opposite the edge of the outside angle-iron ring, when such a ring is used, and along the edge of the inside laps at the longitudinal and transverse joints. We have also known it to occur to a great extent around the lower part of the circumference of circular tube-plates which were flanged forward and placed within the barrel. We noticed this fact in an article on the joints of locomotive boilers in the last number but one of this journal. In the cases to which we have referred, the furrowing took place most deeply at the bottom of the tube-plates, and from that point it gradually diminished up to the water-line, where it almost entirely ceased. As stated by Mr. Kirtley, and in the article to which we have already referred, the result of the strain produced by the pressure of the steam within a lap-jointed boiler is, that a slight springing or bending of the plates takes place at the edges of the joints each time that the pressure is applied, the continual variations in the pressure causing this bending action to be continually going on when the boiler is at work. By this action the coating of scale, which is deposited upon the plates by the water, and which, to a certain extent, would protect the plates from corrosion, is detached at the points we have mentioned, and a fresh surface is thus continually exposed to the action of the water.

"To avoid the defects above mentioned, the boilers of the locomotives on the Midland Railway are now made with welded longitudinal joints, and the three rings of which each barrel is composed have their abutting edge turned in a lathe, and are

united by double-riveted butt-joints, the covering strips being hoops shrunk on, and all the rivet-holes being drilled after the plates and hoops are put together. The plates forming the rings are rolled with thickened edges, a long gradual taper uniting the thick edges with the main body of the plates. At the smokebox and firebox end of the barrel the rings are flanged outwards, so that no angle-iron rings are required to join the barrel to the firebox casing and smokebox tube-plate. Special machines are employed to bend and flange the thickened edged plates. The flanging is effected by laying the plate upon a flat bed, with the portion that is to be flanged over projecting; this part of the plate is then bent down by the descent of a roller. The rolls used for bending these plates have a deep groove formed in them at one end to receive the flange, the width of the groove being adjustable by a large screw and nut. Each ring is formed of two plates, and after these have been welded up, the ring is blocked to the proper diameter and the soundness of the weld tested, by means of an ordinary hydraulic wheel-tyre blocking-press.

"A series of experiments which have been made upon these welded joints show that their average strength is within one-eighth of that of the solid plates; and in more than half the number of strips of plate which have been cut out across the weld and tested by a tensile strain, the fracture took place in the solid plate, and not in the weld. A number of boilers with welded seams have now been in use on the Midland Railway for some years; they are found to be in good condition, and they have as yet shown no sign of furrowing even at the flanged ends, at the points where the grooving action was most marked in the boilers connected to the smokebox tube-plate, and firebox casing by angle-iron rings. Mr. Kirtley exhibited on the occasion of the reading of his paper a number of specimens of corroded plates cut from boilers of the ordinary construction; samples of the thickened edged plates, flanged and bent, and pieces of welded plate that had been broken in testing the strength of the welded joints were also shown."

(b.) "On the 1st inst., the boiler of a locomotive belonging to the Great Northern Railway Company exploded near the Nottingham station. Nobody was killed, and there will therefore be no public inquiry, but the first question which such an occur-

rence suggests to us is—Had the boiler been recently tested? It is curious that, in the face of a mass of evidence in its favour, the hydraulic test is never used on several of our principal railways. The Great Eastern, the North London, the South-Eastern, the Caledonian, and some other companies, do use the test regularly; but on the London and North-Western, the Great Western, and, we believe, also on the Great Northern and several other lines, it is not applied. On the Great Eastern Railway the boilers are tested as far as possible every twelve months, and the system is found to work well. The testing pressure is not excessive, being equal to about one and a half times the working pressure.

“In the course of our own experience we have known several instances in which the application of the hydraulic test has revealed defects which, if not thus discovered and remedied, would, in all probability, have led to the most serious results. We do not consider that the hydraulic test is any substitute for a thorough external and internal examination of a boiler, but it is a most useful auxiliary, and it is a test which can be applied at times when an internal examination of the boiler is impossible. In the case of locomotive boilers especially, an internal examination is an expensive affair, necessitating as it does the removal of tubes, &c.; and, although we are far from advocating that false economy which would begrudge the expense of examining a boiler, yet we know that the question of cost is an important one in connection with boiler working, and for that reason a test which can be cheaply applied is more likely to be used than one involving a great outlay.

“When a boiler is tested by hydraulic pressure, it should be completely stripped, so that it can be thoroughly examined during the time the pressure is applied. It would also be doubtless better if the principal dimensions of the boiler were checked before the pressure was applied, as well as during its application and after its removal, and any differences which may exist noted; but even without such precautions the degree of regularity with which the pressure increases under the action of the pump, and the constancy with which it is maintained, enable a person who has had any practice in the application of the test, to judge very accurately of the state of the boiler under trial. The test is alto-

gether, when carefully applied, a simple and effective one, and we sincerely trust that its use may become extended."

25. *The Action of Water in Boilers.*—"At the last meeting of the Polytechnic Association of the American Institute, Mr. Norman Wiard presented an apparatus to illustrate the sudden rise and fall of water in steam boilers. He had a cylindrical glass beaker about 4in. in diameter and 12in. in height, divided by ten tin diaphragms $\frac{1}{2}$ in. apart. The lower diaphragm had an inch hole through the centre, and the one next above four half-inch holes near the periphery, and all the diaphragms were punched in the same alternate manner, about one-seventh of the area being removed. The object of these diaphragms was to obstruct the escape of bubbles of steam which were formed at the bottom of the beaker. The vessel was filled with water to a level with the diaphragm next to the upper one, and the water was made to boil by a spirit lamp under the beaker. So soon as ebullition commenced, the surface of the water rose about $1\frac{1}{2}$ in.; the action being manifestly due to an increase of volume by so large a portion of the space being occupied by bubbles of steam. On injecting a very little cold water, which was led by a pipe to the bottom of the beaker, the boiling was stopped, bubbles of steam ceased to be formed, and the surface of the water instantly fell to its first level. The experiment was designed to illustrate the cause of the sudden fall of water in boilers on the cessation of ebullition—a phenomenon that has been frequently observed by engineers, especially in boilers having narrow water spaces, where the free rise of bubbles of steam to the surface is obstructed. The boiler may be stopped either by opening the furnace doors, or by starting the feed pump, or by closing the safety valve."

SECTION FOURTH.—EXPLOSIONS OF BOILERS.

26. *Boiler Explosions and Boiler Inspection.*—"Mr. E. B. Marten, the engineer to the Midland Boiler Association, contributed a long paper," says 'Engineering,' "to which was added an appendix of tables upon Steam Boiler Explosions and their records, and on Inspection as a Means of Prevention. This paper on its reading appeared too long and too elementary, and, indeed, the reading of its concluding portion was adjourned until Wednesday

morning. But, of all the papers read, it led to the longest and best-sustained discussion. Mr. Marten dwelt at some length upon the want of sufficient experience and the errors committed by our forefathers in engineering, and referred to the explosion of one of Woolf's cast-iron pipe boilers in London, in 1815, and to the inquiry of a parliamentary committee into the whole subject of boiler explosions in 1817. That committee recommended wrought-iron in place of copper and cast-iron boilers, of which so many were then in use. They recommended that boilers should be tested and periodically inspected, which is what we are still urging, in many cases in vain, after fifty years of additional experience and observation. They recommended that every boiler should be fitted with two safety valves working to one-third only of the test pressure. Mr. Marten then stated that he had collected records of 1046 boiler explosions which had happened (in the United Kingdom only, we presume he meant) since the beginning of the present century. We do not ourselves believe that this is one-half the number that have occurred, the present regular annual rate being upwards of fifty, while twice that number explode annually in the States. Of these 1046 explosions, however, Mr. Marten had collected and recorded the places where the explosions occurred, the names of the owners of the boilers, and the alleged or probable cause of most of the explosions, although 397 explosions were set down under the head of 'uncertain.' In one case a boiler actually collapsed under the pressure of the atmosphere, the steam pressure being only a very few pounds above a vacuum. Mr. Marten glanced at the various theories of the causes of boiler explosions, merely to reject the explanation by the decomposition of gases, by superheating the steam above the water, &c., and considered that all explosions were due to 'over-pressure,' which term was qualified as meaning any pressure above the strength of the boiler at the time of explosion, in which sense the usual working pressure might be an over-pressure, if the boiler had been imperfectly made originally, or had sustained injury from neglect or other cause. Thus the causes of all boiler explosions were referred either to faults in the fabric of the boiler, or to mischief from wear and tear, shortness of water, corrosion, flaws, fractures, &c. We shall not follow Mr. Marten's analyses of the defects of the older forms of

boilers, the cast-iron boiler, the wagon boiler, &c., although we might devote a good deal of space to his criticism of the balloon or haystack boiler, and others used in ironworks, and set generally in the midst of the workmen. Balloon boilers had been made 20ft. in diameter, and there were others of this construction which, although 12ft. to 15ft. in diameter, had been made without vertical stays to tie the top and bottom together. The collection of models and drawings accompanying the paper was remarkably full, but the particulars of explosions and their causes were generally the same as those with which the periodical reports of the various boiler associations have now familiarized us. In connexion with long boilers, 70ft. to 80ft. long—and Mr. Marten might have referred to cylindrical boilers 102 feet long—fired externally, and which had been known to break their backs by the unequal expansion of their top and bottom sides, he mentioned ring boilers, in which a shell, 5ft. in diameter, was formed as a ring of 25ft. outside diameter, or of a mean length, around the centre line of the ring, of 63ft. No form of boiler was especially recommended, nor was any example given of improved construction in boilers; and nothing was said, we believe, of the materials of boilers, and very little as to the mechanical details of their construction. Yet Mr. Marten's paper was very warmly received, especially the suggestion that the Institution of Mechanical Engineers should seek to collect further and consecutive records of explosions and their causes. Mr. Olrick spoke first, in his usual animated manner, in defence of the Field boiler, which had caught a 'rub' from Mr. Marten because of its small water-carrying capacity. Then came Mr. Bramwell, who spoke well, as he always does, but who hinted at the incompleteness of the paper, long as it was, and who recommended that land boilers should be covered with sand to keep in the heat, this permitting, he said, of the condensed steam from leakages being re-evaporated, and always being easily removed if access were required to the plates. Mr. Maudslay followed, urging the importance of the subject upon the Institution. Mr. Fairbairn spoke at some length. He had been the first to introduce the two-flued Lancashire boiler, which had worked well, and ever since he had done so higher pressures had been coming into use. He had paid increasing attention to the causes of explosions, and he had given much of

his time gratuitously, during the last ten years, to the Manchester Association for the Prevention of Steam Boiler Explosions, an institution which had accomplished excellent results, only three or four explosions having happened among the many hundreds of boilers always under its care. He urged the importance of the whole subject upon the score of humanity, more than 500 persons having been killed by boiler explosions in the United Kingdom since the formation of the Manchester Boiler Association, while perhaps twice that number had been more or less injured from the same cause. Lieut.-Col. Kennedy added his testimony to the great importance of the subject, and Mr. J. M'Farlane Gray instanced an interesting case, in which it appeared that a boiler exploded solely in consequence of the safety-valve weights, which were hung upon a spindle on the under side of the valve and within the boiler, having accidentally dropped off. But the best of all the observations were those of Mr. L. E. Fletcher, the engineer to the Manchester Boiler Association, not the Boiler Insurance Association. He summed up all the causes of Boiler explosions in one word—neglect, neglect either by the boiler-maker, the owner, or the man in charge. There was no moonshine, no mystery, in boiler explosions. In almost every case the cause could be clearly accounted for; and where it could not be, it was because the evidence had been destroyed by the explosion itself, and not that the cause was in its nature unaccountable. Mr. Galloway called attention to the strength given to the flues, and to the improved circulation secured by Galloway's conical tubes; and although he did not say so, we believe that there are literally thousands of these now working in Lancashire, and with the best results. We anticipate from the general result of the discussion that the Institution of Mechanical Engineers will yet interest itself, in its official capacity, to lessen, if possible, the frequency of boiler explosions by promoting a more general system of inspection."

27. *Various Points connected with Boiler Explosions.*—(a) *fractures of plates and angle irons; (b) corrosion of plates and angle irons; (c) overloading of safety valves; and (d) overheating,* (from the Report of Mr. Longridge, chief Engineer to the "Boiler Insurance and Steam Power Company," Limited).

(a) "In relation to this class of defects, I may mention one

instance where a boiler 6 ft. diameter, made of $\frac{3}{8}$ plates, with internal furnaces, fractured at the third circular seam from the back end, for a length of about 9 ft. through the line of rivets. Instead of replacing the fractured plate at once, the owner had it repaired by means of a strip of plate about 12 in. and $\frac{3}{8}$ in. thick, placed outside, secured by bolts and nuts, and over this, five bars of iron 2 ft. by $2\frac{1}{2}$ in. by $\frac{1}{2}$ in. placed lengthway of the boiler, and held by 3 bolts at each end. In this state the boiler continued working for some months, at a pressure of 60 lb. per square inch, with water oozing out at the fracture, which it was impossible to make tight; but at length, on my urgent remonstrance, the repairs were properly executed. The fracture in this, as in most other instances, was attributable to unequal expansion and contraction. The external flues were so arranged that the products of combustion passed first along the sides and then returned along the underside to the chimney, a very objectionable arrangement, especially for high pressure boilers.

“In another instance a boiler 7 ft. diameter, made of $\frac{7}{16}$ in. plates, fracture in a similar manner, for a length of 3 ft., owing to the feed water being delivered upon this direct seam, an evil which is very common, but may be easily obviated by shortening the inside pipe and attaching an elbow so as to deliver the water horizontally, a little above the level of the top of the flues.

“Another boiler, 4 ft. diameter, made of $\frac{1}{2}$ in. plates, working at 90 lb. pressure, was found fractured 6 ft. in length in the direction of the circumference.

(b) “The defects which come under this head are much the most numerous, and, moreover, the most dangerous—especially if on the underside of a boiler—from being difficult of detection, and, in case of explosion, attended with more disastrous consequences. As an example, the following may suffice:—the boiler referred to was 29 ft. long by 8 ft. diameter, made of $\frac{3}{8}$ in. plates. On making a thorough examination of this boiler, the inspector found it so thin where resting on the midfeather or centre wall that with a slight blow he struck a chisel through the bottom, and found it in a similar condition the entire length of the boiler. A report to this effect was sent to the owner, pointing out the necessity of replacing the boiler forthwith. In reply, I was informed that subsequent to the inspector's visit he had had the

boiler examined by two competent men—a boiler maker, and his own engineer—both of whom denied the accuracy of the report, more particularly as to the hole made by the chisel. Having perfect confidence in the inspector I promised to send him again to point out the place, but on arrival he found the boiler at work. In the course of two or three weeks, however, the owner called upon me again and acknowledged that the inspector had been right, for on raising steam at the beginning of the week the water made its escape with considerable force, and washed away some of the seating. He then intimated his intention of getting a new boiler as soon as possible, but in the meantime wished to have my sanction to continue working the old one at a lower pressure. The maximum pressure stipulated in the policy was 40 lb., but the inspector had found the safety valve overloaded to 47 lb. I told him I could not guarantee the safety of the boiler at any pressure, and as it was situated under the mill I pointed out the probable consequences in case of explosion. Nevertheless the boiler was continued in use till the new one was ready, and when taken out, the plates along the bottom were found to be even worse than had been anticipated, being in some places not more than $\frac{1}{16}$ inch thick, and in others little thicker than a sheet of ordinary brown paper. The corrosion in this instance was attributable to dampness of the seating and leakage from the lower seams, defects to which all boilers are liable when seated on a midfeather. It may be well to here again mention that in setting boilers of this construction it is best so to arrange the flues that the products of combustion pass along the underside, immediately after leaving the internal flues, and thence return by the sides to the main flue and chimney, all the flues being made of sufficient area to admit of a man passing freely through them for the purpose of examination—an important consideration frequently overlooked.

(c) “The overloading of safety valves is a frequent source of complaint. This is often done in the most reckless manner, totally regardless of the safety of the boiler or the attendant’s own life. In one instance a boiler $7\frac{1}{2}$ feet diameter, insured to work at a pressure not exceeding 30 lb. per square inch, was found working with one safety valve loaded to 81 lb. and the other to 84 lb. per square inch. The safety valve of another

boiler was found weighted to 56 lb. above the pressure stipulated in the policy; another, 31 lb. above the stipulated pressure, by attaching to the lever, in addition to the proper weight, an old pulley, a pipe flange, and another piece of metal, these having been made use of to adjust the load on the valve by the pressure gauge, which, being inaccurate, indicated 17 lb. less than the actual pressure. In another instance where two boilers were proposed for insurance, to work at 20 lb. pressure, the inspector found the safety valve of one loaded to 40 lb., with three pieces of iron, in addition to the proper weight, and that of the other to 67 lb., with eight extra pieces of metal and two hammers. The safety valve of another was found on first inspection with seven bolts, one railway chair, and three pieces of plate, besides the proper weight attached to the lever, and another with five waggon wheels upon the lever. One of the most usual motives for overloading valves is to prevent leakage, where the valves are out of order, and it is difficult, or I might say impossible in some cases, to convince the attendant of the danger of this objectionable practice, from an erroneous opinion which prevails, that so long as any steam is seen escaping from a valve there can be no danger of explosion. A frequent cause of leakage is too broad a bearing surface; as an example, I may mention one instance where the bearing surface of the valve was $\frac{5}{8}$ in., and owing to the surface of the valve or seating, or probably both, not having been accurately faced, steam began to blow off at 40 lb., when the actual pressure on the valve according to calculation was 65 lb. per square inch. The only effectual remedy in such cases is to reduce the bearing surface to $\frac{1}{8}$ or $\frac{3}{16}$ inch.

“Not less than 615 safety valves, as before stated, were found out of order, or overloaded; of these, 51 were entirely inoperative, three having been intentionally made fast by wedges, the others having become so through neglect of cleaning. In one case a piece of india-rubber was inserted between the valve and the seating; in another, a piece of canvas with white lead, to make the valve tight. The worst case, however, brought under my notice, was one where the attendant had actually removed the safety valve, and the inspector found the boiler at work without one, the pressure on his arrival being 42 lb. per square inch. He immediately called the attention of the owner to the foolhardiness

of the attendant, and the risk of explosion, and by orders of the former the fires were at once drawn. The regular attendant had been absent for two days, on account of illness, and his substitute was unable to give any information as to when or why the valve had been removed; but, like many others whom I have met with, he seemed to consider the pressure gauge quite sufficient protection to the boilers, and a safety valve unnecessary. At a subsequent visit the inspector learnt that the valve had been taken off by the mechanic, unknown to the owner, and a steam pipe attached in its place for the purpose of conveying steam for heating purposes to another part of the premises. From this pipe there was a branch to the main steam pipe of two other boilers, but a cock intervened which, when closed, as at the inspector's first visit, shut off all communication, and left the boiler totally unprovided with safety valve. There can be little doubt, therefore, that but for the timely visit of the inspector, an explosion would sooner or later have ensued.

(d) "The cases of damage from overheating, in consequence of accumulation of deposit, have been more numerous than usual during the past year. This appears to have been in a great measure attributable to the long-continued drought during the summer and autumn months. The scarcity of water in many instances prevented blowing off, and the regular cleaning of the boilers, and in some localities where the feed water was drawn from tidal rivers the deposit of salt was so great that the plates exposed to the direct action of the fire became red hot and fractured, necessitating extensive repairs. The greatest damage of this kind has, however, resulted from a common practice of heating the feed water, by allowing the exhaust steam of high pressure engines to enter the cistern or well containing the water. Where this system is adopted, the oil and tallow used for lubricating the cylinders is introduced with the water into the boiler, and combining with the deposit, forms a greasy substance, which, settling upon any plate exposed to the fire, prevents contact of the water, and induces overheating. The evil effects of this method of heating the feed water has not, so far as I am aware, been noticed by other engineers. I shall therefore give the particulars of some of the cases of damage resulting from this cause which have recently come under my observation; and first I shall refer to two boilers

20 ft. long by 5 ft. diameter, with two internal furnaces 2 ft. 10 in. diameter, made of $\frac{3}{8}$ Lowmoor plates, with Adamson's patent flanged seams, both material and workmanship being of the best quality. The boilers were constructed to work at 120 lb. pressure, but on commencing they were only worked at from 80 lb. to 85 lb. per square inch. After being in use a few weeks they began to leak at the seams over the fire, and, soon after, all the furnaces showed symptoms of collapse. Caulking was resorted to, but a few days after leakage recommenced, and the furnaces gradually bulged inwards at the sides. The owners naturally became alarmed, and one of them called to consult me respecting the partial collapse. I told him that the leakage and partial collapse were undoubtedly attributable to overheating, and most probably owing to oil or tallow combining with the deposit from the water and settling upon the plates. I was assured that this was impossible, as neither oil nor tallow were ever put into either of the boilers, and that the water, which was drawn from a well upon the premises, was perfectly clear. I advised him to have the furnaces restored to their original shape, and daily to introduce soda with the feed water. The boilers were accordingly repaired, but had resumed work little more than a week when they gave way a second time, one of the plates bulging inwards from 6 in. to 7 in., and fracturing.

"There being now good grounds for alarm, the same gentleman called upon me again, bringing with him a small packet of deposit which had been taken out of one of the boilers. It was an exceedingly fine powder of a light colour, with here and there small lumps, which, when pressed with the fingers, felt greasy and soft. Putting one of these into the fire it burnt like a piece of tallow, confirming the opinion I had previously expressed as to the source of the evil. On further inquiry I ascertained that although the exhaust steam from the engines did not in this instance enter or pass over the surface of the feed water, as is generally the case, it heated the water by passing through a coil of pipes immersed in the cistern containing it, and was thence conveyed through a long range of pipes for the purpose of warming the mill; what remained uncondensed being allowed to escape into the atmosphere. On inquiring what became of all the condensed steam, I was informed that it flowed back through another pipe to the

cistern from which the boilers were supplied. This at once explained the presence of grease, since much of the oil and tallow used for lubricating the piston and cylinder, escaping with the exhaust steam, would thus be conveyed to the boilers. The flues of both boilers were so much injured from overheating that it was necessary to take them out and replace several of the plates, involving great expense.

“Upon my recommendation the condensed steam was no longer allowed to mix with the feed water, and water from a canal substituted for that from the well, the latter containing a large amount of carbonate of lime, the most detrimental kind of deposit in such cases. This having been done from that time to the present, nearly ten months, there has been no further trouble with either boiler.

“Another boiler which sustained injury from the same cause was about two years old, and of the following dimensions,—viz., 13 ft. long by 5 ft. 2 in. diameter, with one internal furnace flue 2 ft. 8½ in. diameter, made of $\frac{7}{16}$ plates of good average quality. It was seated on a midfeather, the flues being so arranged that the products of combustion passed first along the left-hand side towards the front, thence returning by the right side to the chimney. The boiler was worked at 75 lb. to 80 lb. pressure to supply steam to a high-pressure engine, the exhaust steam from which entered a small cistern containing the feed water, which was thus heated previous to entering the boiler. One night when working as usual, with a pressure of about 75 lb. per square inch, the attention of the fireman was attracted by a sound of escaping steam which appeared to him to proceed from some defect in the flue beyond the bridge, but could not be seen. Observing by the glass gauge that the water was lowering, he went to seek the engineman for advice, and finding on his return that no water was visible in the glass, he immediately drew the fire and left the boiler till the morning. On the following day, having received a telegram informing me that the boiler had exploded, I went to examine it, expecting, on account of the high pressure, to find the whole place in ruins. I was agreeably surprised, however, to find on my arrival that neither buildings nor boiler were disturbed, nor was there any evidence of an explosion having occurred; for, excepting that the engine was not at

work, and no workpeople about, all appeared to be in the usual order.

"In a short time the fireman made his appearance, and I inquired what was the cause of the stoppage. He informed me there was a fracture on the under side of the boiler, and having brought me a candle, I found that on the left-hand side, within about 2 ft. of the end of the boiler, a fracture extended diagonally through a longitudinal seam, about 5 in. in length in one plate, and 6 in. in the other. These plates had evidently been red hot over a surface of about 3 square feet area, and were bulged outwards about $\frac{1}{2}$ in. at the worst part. This overheating could not have been attributable to deficiency of water, the flue being uninjured. I therefore surmised, that it must have resulted from the presence of grease, and on examining the engine, I found the arrangement for heating the water as above described. Upon the surface of the fractured plates inside was found a thick greasy substance, from $\frac{1}{2}$ to $1\frac{3}{4}$ in. thick, somewhat resembling pitch, completely charred where in contact with the plates. This substance, which was inflammable, consisted of oil or tallow, mixed with a little earthy matter, the deposit from the water.

"These, and many other examples which I could adduce, clearly show the evil effects of admitting oil, grease, or tallow into a boiler, more especially if the water contain much carbonate of lime. In such cases small round balls of various sizes, composed of grease and deposit, may generally be found at the bottom of the boiler."

27a. At the general meeting of the Institution of Mechanical Engineers held in November, a paper was read on '*Sellers's Self-Adjusting Injector, and other improvements on Giffard's Injector*,'* by Mr. John Robinson of Manchester. "In the original Giffard's injector for the supply of water to steam boilers by a combined jet of water and steam, the area of the annular opening through which the water is supplied to the jet requires frequent adjustment by hand, by raising or depressing the conical water nozzle by means of a screwed handle, in order to obtain the maximum delivery of water with each particular pressure of steam, when frequent variation of pressure occurs; but the improved injector

* An illustrated article on this invention will be found in 'Engineering for Oct. 12, 1866.

invented by Mr. William Sellers, of Philadelphia, is rendered self-adjusting in this respect, the water nozzle being constructed with a piston at its upper and larger extremity, which works in the external overflow chamber, and forms the separation between the water chamber and the overflow chamber of the injector. By this arrangement, whenever the water supply is in excess, the superabundance escaping into the overflow chamber below the piston raises the piston, and thereby diminishes the annular water orifice; and whenever the quantity of steam in the jet is increased by the boiler pressure rising, the increased velocity of the jet carries with it some of the water from the overflow chamber, producing a partial vacuum under the piston, whereby the piston is depressed and the water orifice is enlarged to the required extent for supplying the exact proportion of water corresponding with the increased supply of steam. As there is no open overflow pipe in this injector, and the overflow chamber is entirely closed, the combined jet entering the receiving nozzle that leads to the boiler is not impeded in its progress by drawing in any air along with it; and no overflow can take place after the injector is once started. For starting the instrument to work, a waste cock is opened just beyond the receiving nozzle, when the steam and water are first turned on; and as soon as the combined jet is established, the cock is closed by hand, and the jet then continues to pass into the boiler without intermission, as long as the supply of steam is kept up, in consequence of the self-adjusting action of the water nozzle, whatever variation may take place in the pressure. An arrangement has also been contrived at the writer's works for rendering the injector self-acting in starting, so as to avoid the necessity of opening and closing the waste cock by hand in starting the instrument to work. For this purpose the waste orifice is fitted with a small valve, fixed on the spindle of the foot-valve that opens into the boiler; and as soon as the foot-valve is opened by the jet becoming established, it causes the smaller valve to close the waste aperture, whereby the escape through the waste pipe is stopped. As a simple means of raising the supply of water from a tank below the level of the injector by the action of the instrument itself, the conical spindle by which the aperture of the steam nozzle is closed has been made hollow by Mr. Sellers, having a small hole drilled through its centre; so

that when the steam valve is slightly opened for starting the injector, a small jet of steam issues at a high velocity from this hole, which is more effectual in exhausting the air from the water chamber of the instrument, and producing the vacuum necessary to raise the supply water, than the same quantity of steam would be if it issued at a lower velocity through the larger orifice of the steam nozzle. The result of the several improvements in the injectors since their first introduction has been a remarkable increase in the delivery of water at the same pressure of steam."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION FIRST, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

- Swann's Safety Valve*,—Mech. Mag., Nov. 16th, p. 311, Illustrated.
Water Tube Boilers,—Engineering, Nov. 16th, p. 367, Illus.
Water Tube Boiler, Dickerson's,—Engineering, Nov. 9th, p. 357, Illus.
Boilers for the Emperor of Abyssinia by Easton and Amos,—Engineer, Nov. 5th, p. 363, Illus.
Boiler Explosions,—Engineering, Feb. 16th, p. 97.
Marine Boiler Incrustation,—Mech. Mag., Jan. 19th, p. 42.
Loss of Heat in Fuel by blowing off,—Engineering, July 20th, p. 43.
Hydraulic Pressure Gauge,—Engineering, Oct. 19th, p. 294, Illus.
Boiler Explosion at Chatham,—Engineer, Sep. 21st, p. 219.
Boiler Explosion at Norwich,—Engineering, Oct. 12th, p. 279.
Naylor's Compensating Safety Valve,—Pract. Mech. Journal for Aug., Illus.
Gamble's Salinometer,—Engineer, May 10th, p. 353, Illus.
Safety Valves, Great North of Scotland Railway,—Engineering, July 6th.
Marine Boilers,—Engineering, May 18th.
Barclay's Injector,—Pract. Mech. Journal, Oct., Illus.
Safety Valve Levers,—Engineering, June 22d, p. 413, Illus.
The Strength of Boilers,—The Engineer, Nov. 9th, Illus.
Overheated Steam Boilers,—Mech. Mag., Nov. 16th.
Notes on Boilers,—Engineering, Sep. 21st.
Locomotive Fire-Box Stays,—Engineering, Oct. 12th, Illus.
Mudholes in Locomotive Boilers,—Engineering, May 25th, Illus.
Boilers at Crossness Pumping Station,—Engineering, June 30th, Illus.
Saunders' Salinometer,—Engineer, Oct. 12th, Illus.
Gamble's Salinometer,—English Mechanic, June 1st, Illus.
Petroleum Fuel,—Engineering, March 10th, p. 170, Illus.
Coke Oven, Lloyd & Co.'s Iron Work,—Engineering, June 15th, p. 402, Illus.
Blast Furnaces,—Engineering, Jan. 5th, p. 13.
Hackett's Patent Safety Apparatus for Boilers,—Engineer, Nov. 9th, Illus.
The Boiler Explosion near Swansea,—Engineer, Nov. 9th, Illus.
Player's Hot-Blast Stoves,—Engineering, Nov. 16th, p. 375, Illus.
Silesian Gas Reverberating Furnace,—Mech. Mag., Nov. 16th, p. 308, Illus.
Steam Boiler Manholes,—Mech. Mag., Nov. 23d.
Locomotive Boilers,—Engineering, Nov. 23d.

DIVISION SECOND.

FUEL—FURNACES—SMOKE CONSUMPTION.

SECTION FIRST—FUEL.

28. It has long been a subject of serious consideration with engineers how best to consume our fuel so that with the smallest per-centage of material we might obtain the largest per-centage of results—nor have they ceased, both through the medium of the press and at the various scientific meetings, to draw repeated attention to the highly unsatisfactory modes in use, and of the importance of introducing others more economical, and in keeping with the advanced science of the day—for the difference between the theoretical value of coal burnt in our furnaces and the actual duty obtained from it, is very large, and by no means complimentary to us. The subject of the economical consumption of coal generally, has received, however, during the year a very great impetus from a discussion which has taken place in parliament, and through the medium of the press directing attention to the fact—by some, however, disputed—that our supply of coal is much less than has generally been calculated, so much so, that the time is not far distant when it will altogether cease, and we shall be thrown upon our resources to discover some other means of obtaining power than that of coal. Space does not allow us to go fully into the details of this discussion; we can at best but give extracts here and there from papers published on the subject. We may state here, that a royal commission has been appointed to investigate into the probable quantity of coal contained in the coal-fields of the United Kingdom, the members of which are the Duke of Argyle, Sir Roderick Murchison, Sir William Armstrong, Henry Hussey Vivian, Esq., George Thomas Clark, Esq., Joseph Dickinson, Esq., George Elliot, Esq., Thomas Emmerson Forster, Esq., John Geddes, Esq., Robert Hunt, Esq., John Beete Jukes, Esq., John Hartley, Esq., Dr. Percy, Joseph Prestwich, Esq., Andrew Crombie Ramsay, Esq., John Thomas Woodhouse, Esq., and Mr.

John Campbell of Islay. The commissioners are to report on the quantity of coal which may be reasonably expected to be available for use; whether it is probable that coal exists, at workable depths, under the Permian New Red Sandstone, and other superincumbent strata; to inquire as to the quantity of coal at present consumed in the various branches of manufacture, for steam navigation, and for domestic purposes, as well as the quantity exported; and how far, and to what extent, such consumption and export may be expected to increase; and whether there is reason to believe that coal is wasted, either by bad working or carelessness or neglect of proper appliances for its economical consumption.

The following, under the titles of the "Coal Question," are taken from "Engineering," under dates of June 15th, and July 20th, 1866:—"It is very seldom that the long and wordy reports of the debates in the House of Commons contain anything of so much practical interest as Mr. Hussey Vivian's speech on Tuesday evening, in moving for a royal commission of inquiry into the subject of our future supply of coal. For the last three or four years it has been very common to hear of its coming exhaustion. Sir William Armstrong, in his address to the British Association at the Newcastle meeting in 1863, dwelt upon the great and rapidly increasing drain upon our natural stores of coal; and Mr. Jevons, in his book, has increased the alarm, and Mr. Gladstone has made the question one of legislation upon the unwieldy subject of the national debt.

"No one can object to a royal commission of inquiry, but well-informed persons will not expect to be made much the wiser by the results of its inquiries. We know that we cannot create coal, that what we have under the surface of these islands is a constantly diminishing quantity, and that its exhaustion is necessarily but a question of time. The fear, of course, of absolute exhaustion is not so pressing as that of the increasing price of coal as the quantity remaining is lessened. Like all questions, that of the future supply of coal has been both ridiculed and exaggerated. There are many who urge that we need give ourselves no trouble in the matter, and there are others, like Mr. Jevons, who, in his book, makes calculations, based upon the geometrical rate of increase in our consumption since the begin-

ning of the present century, which are manifestly of no value, if indeed, they be not ridiculous. Because our consumption of coal has increased, there is no natural law whatever, nor any necessary presumption, that it will continue to increase in the same geometrical proportion, nor, indeed, that it will ever become very much greater than it already is. Mr. Jevons makes out that while we are raising 92 million tons yearly now, we shall require 2,607 million tons in 1961; and he arrives at this, not by a particle of reasoning or any kind of consideration, but exactly as an accountant would work out a sum in compound interest, taking merely a certain annual rate of increase. This he takes at $3\frac{1}{2}$ per cent.; but, because it has amounted to this during ten, twenty, or even fifty years, the fact of itself justifies no possible inference as to the future. It is quite as likely that with the constant discoveries in science, we shall yet require a gradually decreasing rather than an increasing supply of coal. Mr. Samuelson, of Banbury, said in the debate, that he was now producing, with 100,000 tons of coal, the same quantity of iron that would formerly have required 200,000 tons for its manufacture. The steam-engine, when working with as little as 3 lb. of coal per horse power per hour, and which is rather an economical rate than otherwise, is believed to utilize less than one-twentieth of the heat liberated by the combustion of the fuel. In other words, there is what we may call a theoretical possibility that we may yet work engines (we will not say whether steam, air, or gas) with an expenditure of but two ounces of coal per hourly horse power. As for domestic fires, it is notorious that the present waste of fuel is very great. As for our exports, there is a possibility that the increasing 'get' of coal in other countries will, before many years, place them in the position of sellers rather than buyers. At any rate, there is no reason for supposing that an annual increase of $3\frac{1}{2}$ per cent. in our output of coal is to continue for fifty or a hundred years. Those who can remember the comparatively recent introduction of steam navigation, railways, and the electric telegraph, should be prepared for further discoveries of equal novelty and importance.

"And at the same time there is every probability that our natural store of coal is very much greater than has ever been supposed. It may yet be discovered underground where it has never been

suspected, and it is also known to exist at depths of 3,000 ft. to 4,000 ft. and upwards; and, for all that has been said of the difficulty of getting coal at great depths, we may be certain that it is perfectly practicable to ventilate mines as deep even as 700 fathoms, and that the lift of the coal will be quite within the economical capacity of machinery.

We have made, elsewhere, extensive extracts from Mr. Vivian's speech, which was one of unusual interest, breadth of information, and value; and we pass on now to a point which we have not yet seen dealt with, but which has a possible bearing upon the question of coal consumption.

"We have never yet heard the alarm raised that we were exhausting our natural store of air. Yet, vast as is the atmosphere surrounding the globe, we are to remember that, for every ton of coal completely burned, at least 3 tons of oxygen, corresponding to about $13\frac{1}{2}$ tons of atmospheric air, is required for its combustion. Every ton of the carbon of the coal requires $2\frac{2}{3}$ tons of oxygen, and every ton of hydrogen requires 8 tons of oxygen for its combustion. Yet although we have carbonic acid in the one case, and water in the other, as the products, respectively, of combustion, nobody supposes that there is really less oxygen in the world than there was before. It has entered merely into a compound. But so, too, has coal. It is not annihilated, nor can we conceive of the annihilation of any physical element in nature. Burn coal how we may, we merely change the condition of its carbon from a solid to a gaseous compound with oxygen. The coal may cease to exist *as coal*; but it has been the constant custom of writers upon the coal question to argue as if, when burnt, it ceased absolutely and for ever to exist in any form. Now, could science but find the means for the cheap decomposition of carbonic acid, we might have the carbon of our coal again restored to us, to be consumed again as before, and to be again recovered and burnt *ad infinitum*." For the remainder of this paper, see "Engineering," of June 15th, 1866. The following is the article under date July 20th:—"In the preface to the second edition of Mr. Jevon's work on the coal question he states that the as yet unpublished statistics of the Mining Record Office show that the production of coal in the United Kingdom in 1865 was about 95,000,000 tons, thus showing a considerable increase

upon that raised in 1864, which was 92,787,873 tons. A single year's increase or decrease goes for little, perhaps, in an argument as to the coming scarcity of coal; but we have the fact that for a long series of years the rise has been uninterrupted, and that it has unquestionably averaged about $3\frac{1}{2}$ per cent. each year over the production of the previous year. Since 1781 we have raised and consumed not far from 2,600 million tons of coal, and Mr. Jevons, taking the annual rate of increase as constant, finds, by a simple calculation, that our descendants will, by 1961, be raising the same vast quantity in a single year—that while we are now raising 95,000,000 tons a-year, they will be bringing out the last-named quantity every fortnight. The curve of increasing consumption, plotted upon the continued rise in the same geometrical ratio, is a startling one. Taking a scale of years as the base, the ordinates rise very gradually during the first two-thirds of the present century, much more rapidly during the next thirty-four years, while they shoot up into the very clouds of statistics in reaching the wonderful year of 1961. What the population of these islands will then be is not stated. The mere annual rate of increase in the consumption of coal is then to be about 90,000,000 tons—in itself nearly equal to our whole present yearly production.

“Once admit the law of geometrical increase, and, going still further, the rate of $3\frac{1}{2}$ per cent., and all these conclusions are necessary consequences. In a former notice of Mr. Jevon's book we did him the injustice of denying that he had reasoned out his case. In this we went rather beyond what we intended, for our belief is that nothing in history, nor in the present, can be made to justify such an application of a presumed law of increase. Mr. Jevons does bring to bear upon the case abundant statistical knowledge, and he applies it most ingeniously; but, in adopting any given rate of increase, and in making that rate a geometrical one, he launches upon an unknown sea of presumption; or, to drop the figure, he sets up a case which defies reasoning. We should be content to believe of the future, especially the far distant future, that it contains events, conditions, circumstances, and compensations which we cannot possibly foreknow. History is filled with events which could have never been foretold. If we take upon ourselves to say what a century may bring forth, we will engage to say that a clever theory might be

advanced, and supported by numberless analogies, that London, like Lisbon, will be destroyed by an earthquake, and it is but a step further to the great event prophesied by Dr. Cumming. But, with more probability, we may look forward to revolution and civil war, to the destruction of our naval power, and thus to being humbled at the feet of other nations. These are all events which may happen, and none can say when. With all our outlay of money, with all our invention, ingenuity, skill, and perseverance, we have not, at this moment, a navy with which we can certainly defy all other powers. There are those, whose opinions are worth heeding, who tell us that the Americans could sink every ship we possess. With national prosperity we see, in all parts of the world, how the ambition or the passion of nations is multiplying wars. It will be a miracle if England escape unscathed, a miracle if, amid all the elements of international and social discord, we can go on for a century prospering, even to the extent of continued national security. We have these things to think of, and we truly believe the dangers are far more imminent than that of the even approximate exhaustion of our coal. We have much to dread, not from the want of intention, but of practical appreciation on the part of our official authorities. Our greatest danger lies in their official inability to see at once what is good in new inventions in the art of war. We have been four years ridiculing the monitors, and the *Times* now tells us that, in the event of war, they would annihilate our navy, and thus our national greatness for ever. It was not until the Austrian national cause had been lost that our authorities could clearly see the advantage of breech-loading rifles. Fourteen years' preparation by the Prussians, to say nothing of the common-sense view that a gun which could safely fire eight or ten shots a minute was superior to one which could only fire two or three, all went for nothing. We are now recovering lost ground in this respect, but what we have to dread in the future is a fatal surprise, of the very kind which our authorities never expected.

“As for the coal, nearly all that can be said has been said. We have had estimate upon estimate of the quantity remaining, and we know the present rate of consumption, but we cannot pretend that from this we can predict the future rate. We believe, too, that our industry may yet be doubled, even

with our present rate of consumption, for we get but a fraction from the coal of the useful work of which it is capable. Besides, we are sooner likely to fail for iron than for coal. The Bessemer process has disqualified, so to speak, a vast proportion of all the iron ores we possess. Bessemer metal is already preferred to the best irons for rails, tyres, and ship-plates, and there is good reason to believe that it will, within a short time, take the place of iron for all its more important applications. Yet no present skill can make Bessemer metal from the common irons of the Midlands, of Wales, the Cleveland district, or of Scotland. We are already sending abroad for iron stone, and our imports are likely to increase rapidly.

“We are not denying that our coal is a fixed quantity, nor that we are steadily and even rapidly drawing upon it. To sensibly diminish, however, our great natural store even within a century, we shall require to draw upon it at a rate which but few can believe probable. The question is one which no amount of argument can possibly settle, and every one must, after all, be left to his own judgment in the matter.”

29. *Lancashire and Cheshire Coal for Steam Purposes.*—“For many years,” says a writer in the “*Mechanics’ Magazine*,” “the coal-owners of South Wales enjoyed the exclusive patronage of the Admiralty in respect of their coal for steam purposes. Latterly, however, this patronage was extended to the coal-owners of the Tyne, who now share with their brethren of South Wales the privilege of supplying our naval establishments. But it seems that they are not to be left in undisturbed possession of the honour, for the Lancashire and Cheshire coal-owners are now endeavouring to establish their right to compete with other producers in supplying the Government. This right must, of course, be based on the quality of the coal, which must be proved to be at least equal to that supplied by the other purveyors. With the view of ascertaining this point, and of thoroughly testing the adaptability of Lancashire and Cheshire coal for steam purposes, a series of experiments was inaugurated about eight months since at the Kirkless Hall Coal and Iron Works, near Wigan. Very elaborate and complete arrangements were made by the South Lancashire and Cheshire Coal Association, for conducting the test fully and accurately, and experiments of the most searching char-

acter have been carried on continuously since the 18th of October last. These experiments have not been completed, so that the question is as yet undetermined, although, from the results already obtained, the experimenters anticipate a success far beyond that they hoped for. The trial is being conducted by Dr. Richardson, of Newcastle-on-Tyne, and Mr. L. E. Fletcher, the engineer to the Manchester Steam Boiler Association. Although the primary object of the trial is to ascertain the steam-producing qualities of the coal of Lancashire and Cheshire, there is yet another end in view, which is to ascertain by careful observation the comparative worth of the various kinds of steam boilers by the Lancashire makers. In carrying out this twofold object, four boilers were erected in a shed at the Kirkless Hall Works. One of these is an exact copy of the marine boiler used in such experiments at the Devonport Dockyard, and was expressly constructed for these trials. The other three are ordinary Lancashire mill boilers, one having been constructed gratuitously by the Messrs. Hicks, of Bolton, a second by Mr. Clayton, of Preston, also gratuitously, and the third by Messrs. W. and J. Galloway and Sons, of Manchester, who did not, however, respond to the application of the committee to furnish a boiler free, and therefore it became necessary, in order to carry out the trial fully, to purchase one. The appliances to each boiler are of the best description and most scientific make, apparatus being fitted for measuring the quantity of water supplied, the temperature of the water, the pressure of steam raised per pound of coal consumed, and for arriving at other results.

“This trial has already extended over seven months, a much longer period than it was expected would be required to arrive at a result which would justify an application to the Admiralty. Each experiment has, however, been several times repeated in order that it may be perfectly verified, and thus it comes that the trial has not been concluded yet. But although the experiments are not complete, Mr. Fletcher has recently reported progress, and at a meeting of gentlemen interested in the question, which was held last week at the Kirkless Hall Works, he gave some interesting particulars. From what there transpired it appears that the trials of the evaporative value of the coals were steadily progressing day by day. At each of the experiments notes are taken

of the water evaporated, the weight of coal burnt, the amount of smoke evolved minute by minute, the temperature of the atmosphere, as well as that of the feed water and of the gases in the smoke-box, in addition to the amount of draught in the chimney, &c., and all these particulars are carefully tabulated for reference. At the commencement of the trials, an estimate of the task to be performed was arrived at by a consultation of the results of the experiments tried at the Keyham Dockyard, upon the evaporative value of Hartley and Welsh coals, and the highest result given in the list was adopted as the standard which it was thought desirable to reach. At first the South Lancashire and Cheshire coals did not give this result, but after a little practice in burning the coal, and with a modification of the furnace arrangement, it was found that the result obtained was fully equal to the standard set up. A considerable time had necessarily been absorbed in effecting the alterations, as there were numerous points in the arrangement and treatment of the furnace, which materially affected its duty. These points include the level of fire grate and its length, the thickness of fire bar, amount of windage, and the area of perforations through fire door, as well as the construction of fire bridge, area of vent, draught of chimney, &c., all of which underwent modification to a greater or less extent. Then there were questions of stoking, whether the coal was thrown first on to the dead plate and then pushed backwards towards the bridge, or whether it was spread evenly over the bars at once. Further, whether the fires were kept thick or thin, and the perforations in the fire doors kept always open or always closed, or whether they were only to be opened intermittently at each fresh charge of fuel. All these conditions materially influenced the economic working of the furnaces, and necessitated a lengthened series of experiments in order to settle these questions one by one by an exhaustive process. Of course these led to the fixing of certain conditions and dimensions which have been found to give the highest results. What these were it would be premature to state, as the trials are yet incomplete. But the report upon the whole question may shortly be looked for, when we hope, through the kindness of the experimenters, to publish all the details. Without anticipating this report, but simply judging from present results, we believe that at no distant period

the produce of the Lancashire and Cheshire coal-fields will take a high position in the market, backed by the Admiralty certificate of merit. The South Lancashire and Cheshire Coal Association, through whose exertions this trial was obtained, may be congratulated on the fact that the first results of the experiments showed that the coal was not only equal to the standard aimed at in point of economic value, but that it was also practically smokeless."

30. *The Official Trials of Steam Coals.*—On this subject the "Engineer" has the following article:—"At each of the large Admiralty dockyards in this country experimental trials of all descriptions of steam coals have been carried on for a number of years. The results of the experiments at Woolwich and Portsmouth, extending over the last twenty years, from 1847 to 1866 inclusively, have been published in the course of the last eight years in four several returns, the figures contained in which, without laying an undue value on them, are well worth a brief notice. The first of these returns was ordered to be printed by the House of Commons in 1858, and to be reprinted in 1862 (parliamentary paper No. 204 of the latter year); the next is dated 1863 (No. 79); the third, 1865 (No. 365); and the last was lately issued in this year (No. 440, 1866), the first trial being noted down in July, 1847, and the last in March this year.

"The leading idea regulating these trials is, we suppose, to assimilate them as much as is possible—with due regard to the convenience of the dockyard officials—to the conditions of a boiler on board ship. The apparatus used at Woolwich, hence, simply consists of an ordinary marine boiler, but fed with well or river water. It is provided with a tall pipe, out of which the steam escapes direct into the atmosphere. On the top of the boiler is a tank containing exactly 1,000 lb. of water. This is fitted with a long glass gauge for telling the changes of level as the water gets boiled off, as also with a small overflow pipe for regulating its filling to the determinate level. The tank communicates through a feed valve with the boiler, on opening which, by means of a hand-wheel, the water runs down into it by gravity. The spindle of the stop valve is in communication with a simple counter, the indicator of which moves forward a point for each tank-full that is let into the boiler. The coal to be burned is of course accurately weighed, as are also the result-

ing ashes, clinkers, and sometimes the soot. In the tables published in the sessional returns, after stating the name of the coal, with the place from which it was sent, are given:—1, The number of trials from which the average results were deduced; 2, the number of pounds of water evaporated to 1 lb. of coal consumed, calculated from 100 deg. constant temperature of the feed water; 3, the number of cubic feet of water, reckoned in the same way; 4, the percentage of clinkers; 5, the percentage of ash; 6, the percentage of both clinkers and ash; 7, the description of smoke evolved. The different coals tried are divided into three classes: first, Welsh coals; second, north coal; and third, 'experimental' coal, or coal 'not in contract at the time of trial.' The number of trials made for each separate coal vary from one to over fifty. We understand that the quantities burnt average about 12 cwt. to each experiment, though this is not stated in the sessional returns.

"Taking the Woolwich trials, which are the most numerous, the following are the highest and lowest values of each kind of coal for each series of years, estimated from the pounds of water evaporated per 1 lb. of fuel consumed, calculated from 100 deg. constant temperature of the feed water. The trials at Woolwich dockyard, from 1847 to 1848, gave, with Welsh coal, from 7.91 lb. to 10.03 lb. The average of a total number of eight trials was 9.51 lb. Only two kinds of North Country coal were tried, evaporating from 8 lb. to 8.94 lb. In the experiments from 1848 to 1852, Welsh evaporated 7.66 lb. to 9.37 lb., an average of 130 trials, 8.3 lb.; North Country, 6.11 lb. to 9.49 lb.—average of 150, 8.0 lb. Some anthracite evaporated as much as 9.58 lb. of water. The results of the trials from 1852 to 1858 were, with Welsh coal, 7.27 lb. to 9.56 lb.; and an average of 96 trials, 8.37 lb.; North Country, 6.71 lb. to 9.46 lb.—average of 185 trials, 8.44 lb. Some coal from St. Domingo (probably much injured on the voyage) only evaporated 1.29 lb. In 1858 to 1862, the Welsh coals tried evaporated 8.25 lb. to 9.59 lb.—the average of 50 trials was 9.17 lb.; North Country coal, 8 lb. to 8.41 lb.—average of 108 trials, 8.18 lb. Amongst the 'experimental coals,' or coals 'not in contract at time of trial,' was some patent fuel of Covill & Co., evaporating an average of 9.22 lb., and some of Warlick's patent fuel, evaporating 9 lb. of

water per pound of fuel. From 1862 to 1865, Welsh coals are put down at from 8.83 lb. to 9.66 lb.—average of 33 trials, 8.9 lb.; North Country coal, 7.9 lb. to 8.24 lb.—average of 61 trials, 8.08 lb. In the course of the experiments in 1865 and 1866, Welsh coals made from 8.1 lb. to 9.9 lb.—average of 15 trials, 9.08 lb.; North Country, 8.12 lb. to 9.21 lb.—average of 23 trials, 8.62 lb. Adding up the results of the nineteen years, we find that the highest and lowest values, and the average of all the trials were respectively—Welsh coal, 7.27 lb. to 10.03 lb., with an average of 8.89 lb.; North Country, 6.11 lb. to 9.49 lb.—average, 8.3 lb. Amongst the experimental coals tried were some from Borneo, from Formosa, Chili, Singapore, Tasmania, New Zealand, and other places, besides a great number of the different patent fuels. ‘Cardiff compressed steam coal,’ when tried this year, gave, on an average of four trials, 9.47 lb. of water per 1 lb., with a percentage of clinker and ash of 8.23, and with ‘rather light smoke.’ Ten trials of some coal from Nelson, New Zealand, were made. Notwithstanding that the voyage must necessarily have somewhat damaged these coals, one of them gave the very high average of 9.9 lb. of water evaporated per 1 lb., with only 3.37 percentage of both clinker and ash. The lowest result was 9 lb. of water per 1 lb. of coal, with 4.85 percentage of clinker and ash. The first description was found to cake in burning, making a ‘hollow fire,’ and ‘forming a small quantity of light clinkers that did not adhere to the bars.’ A considerable quantity of white ash passed up the chimney, leaving a dark grey sandy kind of dust in the tubes and fire-box. The smoke was ‘small in quantity,’ but the ‘coal is tender and likely to break small on being removed from ship to ship.’ Another kind of ‘Nelson, New Zealand,’ was more like the Hartley North of England coal, and it gave off a black smoke. No stoking tool was used with such a low percentage of clinker as from 0.37 to 0.91. ‘Nothing seems to be required beyond turning the coals in the fires, and the quantity of ash and clinkers is not greater than that of the North of England coal.’

“Of course little scientific value could be claimed for these experiments, but, carefully conducted, a full publication of all the conditions besides the results of the trials ought to be of great practical value. It is needless to say that what is given in these

returns is insufficient. A reader has to guess at the temperatures of the feed water, a most important item. Again, amongst the further particulars that ought to be given are evidently the duration of time of each experiment; the average amount of coal put on at each operation of stoking; and the amount of water per hour evaporated per square foot of grate surface. These further details would, of course, greatly raise the value of the returns beyond that deducible from the mere juxtaposition of their figures."

31. *The Theoretical and Actual Power of a Pound of Coal.*—"The best anthracite coal contains 98 per cent. of carbon. Favre and Silberman found that if all the heat is utilized, one pound of carbon in burning will generate sufficient heat to raise the temperature of 8,080 pounds of water one degree of the centigrade scale; and, according to Andrews, it will heat 7,900 pounds one degree. Taking the smaller of these results, 7,900 pounds, and reducing it, we find that one pound of carbon will raise the temperature of 14,220 pounds of water one degree of Fahrenheit's scale. Multiplying this by Joule's equivalent, 772, and we have 10,977,840 foot-pounds as the quantity of work which one pound of carbon will perform. If we suppose it burned at the rate of one pound per hour, by dividing the foot-pounds of work by 33,000 and by 60, we shall have the horse power $5\frac{1}{2}$. If all its heat could be utilized, therefore, we should have a horse power from $\frac{2}{11}$ ths of a pound of coal per hour. This point is worth remembering, that theoretically we should have a horse power from two-elevenths of a pound of coal per hour.

"The very best engines give a horse power from about two pounds of coal per hour, and it is a good engine that produces a horse power from four pounds of coal per hour. An engine that gives a horse power with two pounds of coal per hour utilizes in work about nine per cent. of the whole power of the coal; and one that yields a horse power for four pounds of coal per hour utilizes about four-and-a-half per cent. of the power of the coal."—*Scientific American*.

32. *Experiments on Coal* (see par. 29 for the opinion of another authority upon this subject).—From an article in "Engineering" we take the following:—"Since October last, a valuable series of experiments has been carried on at the works of the Wigan Coal and Iron Company (formerly the Kirkless Hall Coal and Iron

Company), at Wigan, with a view of ascertaining the best mode of burning Lancashire coal, and determining its evaporative value. The experiments have been undertaken with the object of placing the coal of the district on an equality with the coals from South Wales and the north of England, and thus obtaining for it the advantage of a place on the Admiralty list; and they are being carried out by Dr. Richardson, of Newcastle, and Mr. L. E. Fletcher, the engineer to the Manchester Association for the Prevention of Steam Boiler Explosions. As much interest had been manifested in the progress of the experiments, a meeting, which was attended by many of the members of the South Lancashire and Cheshire Coal Association, was held at the works of the Wigan Coal and Iron Company, last Monday week, when a report of the trials was presented by Mr. Fletcher, and the arrangements used for the experiments inspected.

“From Mr. Fletcher’s report, which was very complete, it appeared that the results of the trials were exceedingly satisfactory. In conducting the experiments, notes were taken of the weight of coal burnt, and the quantity of water evaporated, as well as of the temperatures of the feed water, of the gases in the smoke-box, and of the atmosphere, and the amount of draught in the chimney. Observations were also constantly made of the amount of smoke evolved. At the commencement of the trials, the results obtained at her Majesty’s dockyard at Keyham, during some experiments on the evaporative value of Hartley and Welsh coals, were consulted, and it was determined that the highest of these results should be adopted as the standard which it was desirable to reach. The preliminary experiments were conducted with one kind of coal only, the object being to ascertain the manner in which this coal could be most effectively burnt under a boiler having the cramped proportions of that used at the Keyham dockyard. In carrying out this plan, the arrangement of the furnace had to be frequently altered; thus the fire-grate was tried at various heights or distances from the crown of the furnace; the length of the grate and the thickness of the bars were also varied, and so were the amount of windage, the area of the perforations in the fire-door, the description of the fire-bridge and area of the vent, the amount of draught in the chimney, &c. Experiments were also made upon the different methods of firing, the coals

being in some instances thrown on to the dead plate and then pushed forwards towards the bridge, and in others spread over the fire at once, whilst thick fires and thin were also tried, and the perforations in the fire-door were in some cases left open, and in others opened intermittently on the addition of each fresh charge of fuel.

“The experiments have thus involved a considerable amount of labour, but the preliminary investigations have been concluded, and the trials are now to be extended to various kinds of coal. As we have already mentioned, the results obtained have been very satisfactory, it having been found that the South Lancashire coal can be burnt without the production of smoke, and that it possesses great evaporative power. On the day on which the meeting was held, 11·079 lb. of water were evaporated by 1 lb. of coal, and 47·912 cubic feet of water per hour were evaporated in the experimental boiler—this was an excellent result. The experiments have throughout been conducted with the greatest care, and whenever a result has been obtained, which seemed to the experimenters to be somewhat exceptional, the experiment has been repeated in order to avoid the chance of error. It has been found, contrary to general expectation, that the best results were obtained with Lancashire coal by thick firing. This result seemed to the experimenters to be so contrary to previously accepted opinions that the trials of thick firing were repeated in every possible form before the accuracy of the results were acknowledged. Altogether, the series of experiments now in progress at Wigan is a very valuable one, and, when completed, the data which it will afford will be a most useful addition to our information on the subject of coal-burning.”

33. *Peat Fuel*.—The following paper on ‘Manufacture of Compressed Peat Fuel’ was read before the Institution of Mechanical Engineers, by Mr. Charles Hodgson. “Improvements on the ordinary mode of preparing peat fuel have attracted much attention for many years. All who have considered the subject have felt that the chief difficulty lay in drying the wet peat obtained from the bog; and to accomplish this numerous plans have been tried, for expressing the water from the saturated peat by power, or evaporating it by artificial heat or air currents after having moulded the material into some brick-like form. But none of

these methods have been practically successful, because they required that great masses of wet peat should be manipulated before drying; and because air-drying the moulded blocks proved too slow, and artificial drying far too costly an operation. A system which had in it the elements of success and differed essentially from all previous plans was, however, proposed by Groynell and others about fifteen years ago. Their idea was to cut peat in the ordinary way and air-dry it to the extent that was possible during the summer in the climate of Ireland; then to grind it and complete its desiccation whilst in a state of powder; and subsequently to compress it in a machine provided with a reciprocating ram, and several moulds capable of being brought successively under the ram. A beautiful sample of hard fuel was thus obtained, but unfortunately the quantity made was limited to samples; for the action of these machines with their moving moulds was complicated, and the strain on the parts was so severe that breakages were of constant occurrence. In addition to these difficulties it was found that the hard and perfect article desired could only be produced when the ram was made actually to stand still at the furthest point of its stroke, and retain the block of peat under pressure for several seconds. The longer it was thus held without being allowed to expand, the more perfect the block became; but if the pressure was removed at once, as in the case of an eccentric of uniform motion, however slow, the elasticity of the peat was not overcome, and more or less of cracking and abrasion would take place within the next few hours. But in the course of these experiments, tried in 1850 to 1853, the fundamental difficulty of obtaining a large and constant supply of dry peat was never even encountered, because the compressing machinery never stood the test of actual continuous work. Even had these machines been then perfected, it would soon have been found that to grind peat already fit for fuel, and afterwards compress it, would be ruinous in cost; and that to dry artificially peat taken wet from the bog would absorb all the fuel produced and leave none for sale.

“The practical difficulties which beset all early attempts in the manufacture of peat fuel have now, however, been overcome by the system and machinery employed at the Derrylea Peat Works, near Portarlinton, where the manufacture of compressed peat

fuel has been regularly carried on for some time, upwards of 5,000 tons of the compressed peat having been already made there and sold in various parts of the country. The system at use in these works is based on the principle that the drying of the peat is the main difficulty of the manufacture; and this is accomplished by operating continually on thin surfaces of disintegrated peat, instead of on compact sods or blocks; while the compression afterwards employed is used only as a means of rendering the already prepared peat transportable and marketable. The system of drying by thin surfaces is also further carried out by the plan of obtaining the peat from the bog by successive harrowings and scrapings.

“The portion of bog at the Derrylea Peat Works at present operated on for the purpose of obtaining the partially dried peat powder or ‘mull,’ which forms the raw material for manufacture, is about 1,200 yards long by 100 yards wide, covering 24 statute acres. A deep head drain cuts off this area from the remainder of the primitive bog; and it is itself drained by transverse covered shores about 20 yards apart, running from this head drain to another main drain parallel to it, which forms the opposite boundary of the patch, and runs, in fact, along the edge of the bog and falls into the natural drainage of the district. The covered shores are simply and cheaply formed by cutting drains in the bog about 4 ft. deep and 2 ft. wide at the top, sloping in the sides so as to leave the bottom 1 ft. wide; in this bottom a square groove about 6 in. in width and depth is formed with a tool adapted for the purpose, called a ‘double-winged slane.’ Sods cut square from the top of the bog are now placed across the top of this groove; and the peat excavated from the drain is again filled in and levelled on the surface. These drains cost about 2d. per yard, and are very effective; they have been used in many parts of Ireland in draining for agricultural purposes.

“A railway of the 5 ft. 3 in. Irish gauge, formed of 36 lb. T-rails well fished at the joints, runs along the centre of this drained piece of bog, being 50 yards distant from each of the main drains. It is laid on sleepers of native timber, and carries an 8-ton locomotive without requiring any ballast on the roadway. On these rails runs a six-wheeled truck, 24 ft. long, substantially built; and across this truck is laid a square box-lattice girder, 300 ft.

long, reaching over the entire width of the drained ground. This girder is formed of $1\frac{1}{2}$ in. angle-iron at the corners, latticed on each of the four sides with flat bar iron $1\frac{1}{2}$ in. wide by $\frac{1}{4}$ in. thick, leaving 2 ft. spaces; it is 6 ft. square at the centre, where it rests on the truck, and tapers to 1 ft. square at each end, and is stayed perpendicularly and laterally by wire rope stays set in taut. This apparatus is propelled by a 6-horse power portable engine, geared down five to one to the wheels; and it is worked at the rate of about 4 miles per hour, with its great arms stretching over the bog at each side to a distance of 150 ft. To these are attached ten or twelve harrows, each 6 ft. square, which by repeatedly passing over the ground scarify it and pulverise the surface to a depth of from 1 in. to 2 in. This operation is performed during any moderately fine weather; and in the mornings and during the day the light powdered surface, which readily dries to a certain extent, is wheeled by men to the side of the railway and waggoned into the works for manufacture.

“In dry weather the upper surface of the bog, thoroughly drained as it is, will always contain much less water, perhaps less than half what the general mass retains; and as by this mode of operation a fresh upper surface is being daily exposed, it follows that peat in the most favourable state for drying is being constantly operated on. As soon as the harrowing begins, rapid air-drying takes place, and a very large portion of the water which is not removed by drainage is evaporated by a few hours' exposure. The mull when waggoned into the factory is generally found to consist of about 40 per cent. peat and 60 per cent. water. This may be considered at first sight as but a poor result to attain; an examination, however, of the state of the bog in its various stages will show that it is not so, the percentage of water and peat contained in the bog being as follows:—In its primitive state, 90 of water, 10 of peat; when drained as described, 84 of water, 16 of peat; upper surface of drained portion, 75 of water, 25 of peat; after some hours of an average dry day, 60 of water, 40 of peat. Hence in any method which commenced by working with the primitive bog, 10 tons of material must be dug out and manufactured for every ton of fuel obtained, and if merely well-drained bog be used, 6 tons must be carried for every ton produced. But in the system now in operation it will be seen that

only $2\frac{1}{2}$ tons of material are required to make the 1 ton of fuel, all the remaining water having been got rid of before the peat left its primitive position.

“Thus far the atmosphere may be relied on to perform the difficult duty of drying; and having attained to the state of not more than 60 per cent. water with 40 per cent. peat, it becomes quite possible to employ artificial heat with economy so as to complete the desiccation. At Derrylea the only artificial heat used is that which is obtained from the waste steam of the compressing engines, and the smoke and gases from the boiler fires, which would otherwise pass direct up the chimney. These are applied in the drying kilns to heat very extensive surfaces formed of sheet iron, on which is spread a thin layer of peat mull, kept in continual and progressive motion by machinery.

“The drying kilns consist of four long chambers, each 500 ft. long by 16 ft. wide inside, containing an upper and lower floor of thin sheet iron plates extending the entire length. The walls are of brick, and the kilns are roofed with tiles, which are found well suited to the purpose, giving through their joints sufficient ventilation, and being themselves good non-conductors of heat. The lower roof is composed of $\frac{1}{8}$ in. sheet iron plates, riveted together, which are carried at a height of 18 in. above the ground by a number of clay pipes set on end at about 3 ft. distance apart. Underneath this floor is blown the smoke and waste heat from the boiler fires; and instead of the ordinary chimney a large fan is used to urge the fires and force the products of combustion under the floor along the entire length of the kilns.

“The upper floor is 4 ft. above the lower one, and is made double for the purpose of being heated by the waste steam from the engines. It is composed in each kiln of five sheet-iron steam chambers, each 500 ft. long and 3 ft. wide, formed of flat plates at top and dished plates below, the two plates being riveted together steamtight along each side with a continuous space between them $2\frac{3}{4}$ in. deep in the centre. These steam chambers are made of sheet iron $\frac{1}{8}$ in. thick, and are carried on cast-iron girders placed 10 ft. apart, and they are arranged so as to overlap one another along the sides. An angle-iron rail runs along each side of both the upper and lower floors, at about 3 in. above their level, and along these rails run wheels, which carry endless chains

and the iron rakes for stirring and carrying forwards the peat mull. The rakes are placed at intervals of 4 ft., and motion is given to them by means of hexagonal drums, round which the endless chains pass at each end of the drying kilns, whereby the rakes are kept in continuous motion at the rate of about 100 ft. per minute. The peat mull as brought from the bog is fed on to one end of the upper floor, and being gradually dragged along by the rakes to the far end of the kiln it there falls down on to the lower floor, along which it is then brought back by the rakes in the same manner. During this drying process in the kilns almost the whole of the 60 per cent. of water which the mull contained is evaporated, and the mull is then in a fit state for being compressed. By an arrangement of bands and elevators the dried mull is conveyed into a loft over the engine room, whence it descends through spouts direct into the mouths of the two peat presses below.

“One of the two peat presses is shown in figs. 1 and 2 of the accompanying engraving. (Not given here.) Fig. 1 is a longitudinal section, and fig. 2 a plan of the press. The strong cast-iron frame N N carries the driving shaft O, which is 7 in. diameter and has forged on it the eccentric P, giving a 7 in. throw. This actuates the horizontal ram R of steel, 4 in. diameter, and the ram moves $3\frac{1}{2}$ in. into and $3\frac{1}{2}$ in. out of the breech of the very strong steel tube S, which is 3 ft. 6 in. long with 4 in. bore. This tube is made of Bessemer steel, bored cylindrical throughout, and turned down outside in a series of cylindrical steps fitting accurately into the cast-iron block T, which is secured to the frame N of the press. The spout U brings down the supply of peat mull from the loft above, and the column of dry mull which it contains rests on the moving ram R as it enters and recedes from the breech of the tube S. At each back stroke of the ram, in the position shown in fig. 1, a portion of the mull falls down and fills the empty space which has been left from the previous forward stroke of the ram, and this material is pushed by the ram into the tube. After a few strokes of the ram the peat driven forwards in the tube becomes so wedged in that a very powerful resistance is offered by the friction against the sides of the tube, so powerful, indeed, that each successive charge is consolidated into a separate hard block before the whole

mass in the tube yields, and it then moves forward about $1\frac{1}{8}$ in., that being the length of one block of the compressed peat formed by the compression of about 4 in. length of peat mull at each stroke.

"The outer end or nozzle of the tube S is left entirely open, and the compressed peat is delivered from it in a continuous cylindrical bar, which readily breaks up into separate discs of $1\frac{1}{8}$ in. thickness each, that are formed one at each stroke of the ram. These discs weigh $\frac{1}{2}$ lb. to $\frac{3}{4}$ lb. each, and about forty of them are formed per minute by as many strokes of the ram. As the tube, however, is 3 ft. 6 in. long, each block remains about one minute under pressure, which is an essential feature of the process; and the quality of the compressed peat as fuel is further improved by its being made to pass along an open trough continued from the end of the tube to about 300 ft. length from the machine to the peat store or waggon, without rupturing the continuous cylindrical bar in which the peat issues from the machine. At the end of this trough the separate discs of the peat, having become by that time loosened, fall out successively, one being delivered for each stroke of the press.

"As this mode of preparing the peat frees it so completely from moisture, it is natural to expect that its duty as fuel will be greatly improved by the process; and it is accordingly found that the peat thus prepared is capable of performing nearly double the work of average common peat, and from 60 to 66 per cent. of the duty of good coal. It is well adapted for the boilers of stationary engines, and for brewer's work; and has found a ready sale for household purposes, its great cleanliness and freedom from smoke being a strong recommendation. The stowage room required is just the same, weight for weight, as that of coal. A very good gas is made by using one-third of cannel coal and two-thirds of this compressed peat; but it is probable that from the application of the peat to the manufacture of iron the most useful results will yet be derived. This fuel has already been applied in the cupola for casting purposes with complete success; and, although it requires peculiar treatment, yet there can be no doubt that, possessing as it does many of the good qualities of charcoal, it will become rapidly adopted for most metallurgical processes wherever it can be obtained."

34. *Peat in Locomotives.*—As closely connected with the subject of last paragraph, and as showing the latest recorded trials of peat as a fuel for consumption in steam engine furnaces, we give the following article on “Peat in Locomotives,” for which we are indebted to the “Mechanics’ Magazine:”—“Attention has been recently turned in America, as well as in England, to the utilization of peat as a fuel, and for making gas, and some discussion and experimenting has taken place upon the subject. As a material for the manufacture of illuminating gas it has been made in both countries the subject of tests which were highly satisfactory. In England Mr. Versemann made a series of experiments, at the works of the Commercial Gas Company, with condensed peat. For gas making he found it superior to many of the best Newcastle gas coals, and quite equal to several descriptions of cannel coals now in use for the purposes of gas manufacture. At Lansingburgh, in the State of New York, Mr. Hanford, superintendent of the gas works, also made some interesting experiments in the manufacture of gas from peat taken from a local deposit. The gas there produced was pronounced to be in every way superior to that made from coal. But it is not so much with peat, as a material for gas making, as for use as a fuel in locomotives, that we have now briefly to deal. We have been led to notice the subject from having observed a paragraph in an American paper to the effect that a train recently ran 43 miles on the Hudson River Railroad, on 4,300lb. of peat, or equal to 100lb. per mile. Now, this result was far exceeded four years since on an Irish railway; and as it is interesting to show what can be done with peat, we will give the details of the locomotive trial. The experiment was made on the Belfast and Northern Counties Railway, with a train of seven carriages, the total weight, including engine and tender, being 70 tons. The distance run was 74 miles, and the time occupied in the journey 3 hours and 9 minutes, including stoppages. The total quantity of peat fuel used was 14 cwt. 1qr. 14lb., or 1,610lb., the average weight per mile being 21·47lb. In order to compare the consumption of the two kinds of fuel—peat and coal—we may observe that at the time of this trial (1862) the average quantity of coal was much higher. In fact, the average per mile for three months prior to the trial, using Welsh and Scotch coals at a ratio of 2 of

Welsh to one of Scotch, was 25·25lb. The average for one month was 26·29lb.

“The trial was superintended by Mr. Yorston, the locomotive engineer of the line on which the experiment was made, Mr. W. H. Stephenson, engineer of the Ulster Railway, and Mr. Denville, engineer of the Belfast and County Down Railway. During the whole of the journey the experimenters had an excess of steam, notwithstanding that the fire-door was constantly kept open and the damper down for the greater portion of the distance. The pressure at starting was 100lb. on the square inch. The commencement of the journey was up an incline of about 1 in 80, four miles long and with double curves. Whilst going up the incline the pressure rose to 110lb. and afterwards to 120lb., the fire-door being open all the time. Whenever circumstances permitted—for it was an ordinary working train—the speed was 40 miles per hour, and it was remarked that while travelling the fuel emitted no smoke, and very little when the engine was standing at stations. At the close of the journey the fire-box was examined and a very small portion of clinker was found; considerably less than would have resulted from the best steam coal. On looking into the smoke-box, it was found to be perfectly free from cinders or dust, thus proving that the fuel stood the blast exceedingly well. From a careful noting of all these facts the experimenters came to the conclusion that the condensed peat was in every way well adapted as a fuel for locomotive purposes. Now in contrasting the results of the American trial, which shows 4,300lb. of peat consumed in a distance of 43 miles, with the Irish trial, which gave 1,610lb. of peat and 74 miles, we must bear in mind that the conditions of the two trials may have been very different. We have no details of the American trip to guide us in our conclusions; we should like to see them given. In the Irish trip condensed peat—specially prepared by machinery—was employed, whilst in America an unprepared and consequently a very inferior article may have been used. There are other conditions affecting the matter, such as weight of train and engine, character of road, &c., so that any comparison would be unfair, being based upon insufficient data. Enough, however, is shown to prove the value of peat in both countries as a fuel for locomotive purposes, and we trust the question will not be lost

sight of. Indeed, it is one which deserves careful attention, and every endeavour should be used to render profitable the six million acres of peat which have hitherto proved but a nuisance and an eyesore to Great Britain."

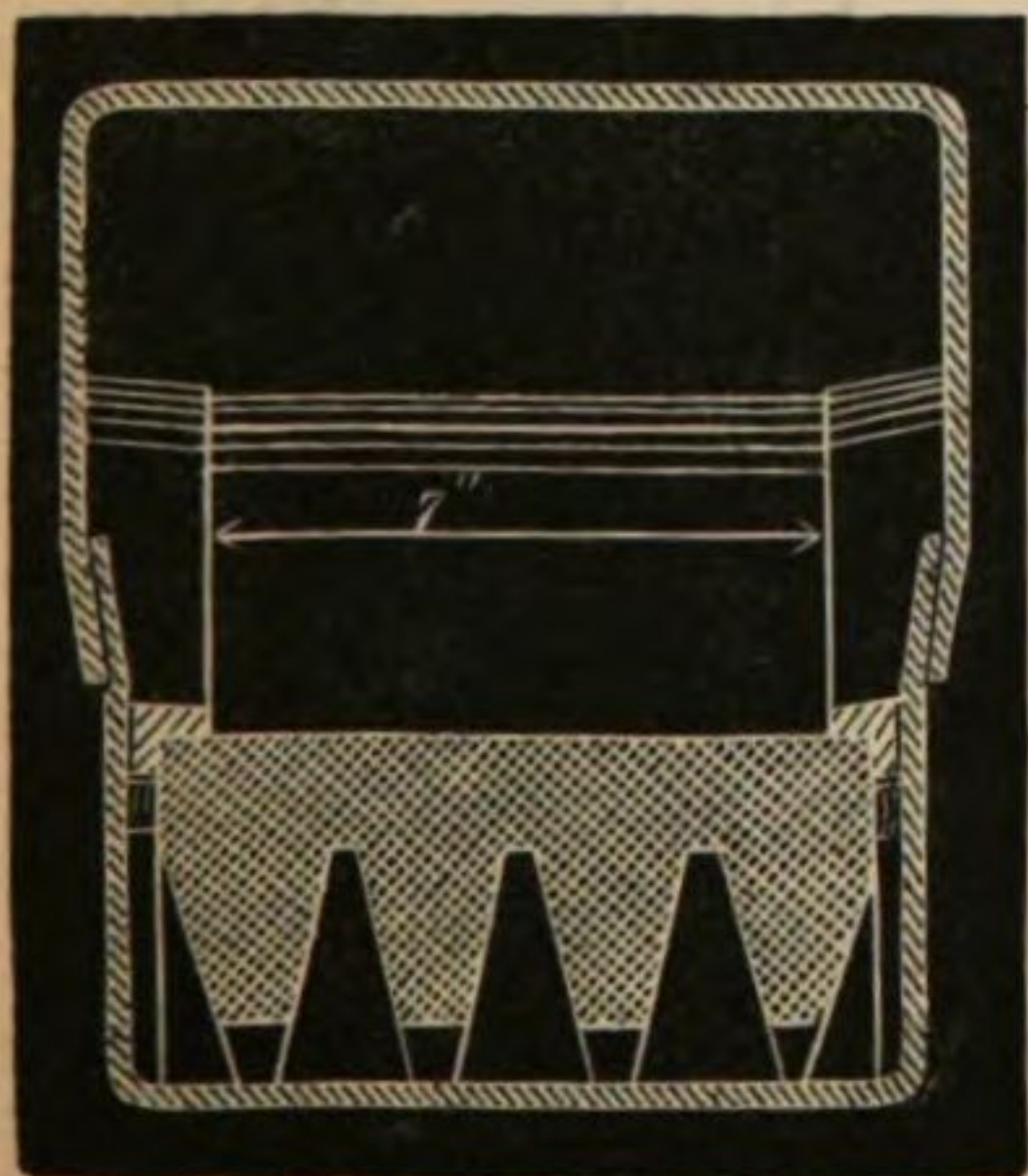
35. *Petroleum as a Fuel for Steam Engine Furnaces.*—The remarkable properties of petroleum, the vast quantities which have been obtained of it, and the apparently almost exhaustless resources which are being daily discovered, have naturally directed attention to its utilization in many of the branches of the arts. In connection with that branch in which the readers are more specially interested, the efforts of Mr. Richardson have been very marked. The following remarks upon the use of petroleum as a fuel for steam engine purposes we take from "Engineering:—" "Petroleum in its crude state is a compound of a spirit (called mineral naphtha, or petroleum spirit), a burning oil, and heavy petroleum. The proportions of these three elements (which may be separated by distillation) vary greatly in different samples; some kinds evolve inflammable vapour at a low temperature, and are, consequently, readily ignited; while in other varieties, such as the heavy oils of Rangoon, Egypt, and the West Indies, as well as in the English coal oils, the quantity of spirit is small, and the oils, consequently, only vaporise at a high temperature. During the past year, the question, whether petroleum can be advantageously employed as a fuel for marine boilers, has been considerably discussed, and numerous experiments have been made at Woolwich by Mr. C. J. Richardson to test the evaporative power of the material, and to ascertain the best method of utilizing it. Mr. Richardson first directed his attention to the formation of an artificial coal by the admixture of the oil with any porous material, and the results then obtained convinced him that petroleum could be best consumed by the aid of a porous stone wick dipping in a trough containing the oil.

"The first grate made on this principle consisted of three porous bars or wicks of a T section, the vertical portion of each dipping into a trough containing petroleum. The three troughs were connected at the end next the chimney by a transverse chamber, on the top of which was fixed an arched tube perforated with small holes, through which the vapour arising from the petroleum could escape. Each of the oil troughs was surrounded by a cham-

ber through which the feed water of the boiler was made to pass, and the oil was thus prevented from becoming unduly heated (as it has a tendency to do) when the apparatus was at work. The grate was first tested under a cylindrical boiler at Chelsea, which, when worked with coal, used about 12 cwt. per day, and, when the water was cold, required wood and about 3 cwt. of coal to get up steam. The draught passed direct from the grate along the bottom of the boiler to the chimney, and at the time of the first experiments, the brickwork was wet, having been just renewed. On that occasion the temperature of the water in the boiler was only raised 30° in $2\frac{1}{2}$ hours with the consumption of rather less than two gallons of oil; the feed water which passed through the grate running to waste, and escaping at a temperature of from 168° to 247° . The quantity of feed water was too great, and the flame was kept very low in consequence. An alteration was then made, the inlet and outlet pipes of the water chamber being connected with the boiler itself, and under these circumstances steam was raised in about three hours, $2\frac{1}{2}$ gallons of crude petroleum being consumed. The vapour tube did not act in these experiments, owing to the vapour chamber being too low.

"The grate was next removed to Woolwich, and, by permission of the Admiralty, placed in a 14-horse boiler there. Steam was raised in $1\frac{1}{2}$ hour with an expenditure of 4 gallons of oil; but the grate not having been constructed to bear the pressure to which it was subjected, cracked and opened at the joints, causing a waste of oil.

Fig. 14.



"The improved grate now used by Mr. Richardson is shown by the accompanying illustration, Fig. 14. The casings, which are of wrought iron, form part of the boiler, and are fixed in it in the same manner as an ordinary fire-box. The boiler is 6 ft. by 5 ft., by 4 ft. 11 in., and contains four of these fire-boxes. The fire-bar or 'wick' is fitted into a deal frame, and extends across the casing, dividing it into two parts, of which the lower acts as an oil chamber and the upper as

a fire-box. The deal frame is protected from the action of the flame by a layer of fireclay placed over it, as shown in the figure. The best material for the wicks is found to be either the moulded carbon used for filters, or the ordinary founder's loam—the latter being the substance used at Woolwich. A wick may, however, be formed of any porous material covered with a layer of powdered lime, charcoal, or salt, about half an inch thick; and it is found that, during the combustion of the oil, there is deposited upon the surface of the wick a layer of petroleum coke, which, being a highly porous material itself, forms an excellent wick. The air is supplied to the furnace by an opening in the door about 6 in. by 1 in., fitted with a perforated plate, and a small quantity of air is also admitted at the back of the combustion chamber. The petroleum is supplied to the grate by pipes leading from a tank containing it, and as the heavy oil, which can be most advantageously employed as fuel, contains little or no spirit, the tanks can be placed close to the boiler, and the heat from the latter will then render the oil fluid.

“To start the grate when the water is cold it is necessary to employ a light oil which can be readily absorbed by the wick, such, for instance, as the pure petroleum or the first product obtained from the crude oil by distillation. This can be contained in a tank, and be supplied to the grate by a pipe in the same manner as the heavier oil, the supply being shut off when the apparatus becomes warm. The petroleum grates require no ash-pit, and two of them therefore occupy no more space than an ordinary fire-box.

“During Mr. Richardson's last experiments at Woolwich, from 12·96 lb. to 13·66 lb. of water was evaporated by the combustion of 1 lb. of American petroleum, and as much as 9·7 lb. of petroleum per square foot of fire-grate was in some cases burnt in an hour. With coal oil, the evaporation was rather less, and with shale oil still less—about 10 lb. or $10\frac{1}{2}$ lb. of water per lb. of oil. Unfortunately the boiler was never in use for a longer period than $3\frac{1}{2}$ hours at one time, but the results obtained seemed to indicate that a more extended trial would be favourable to the economical use of the oil. It is expected that further experiments will be made shortly, and that the working of the apparatus will then be tested for longer periods. During the trials that

have already taken place, the wicks have shown no tendency to clog; but, if under continuous working they should do so, they could be easily cleaned by running through them a little spirit or gasoline, or natural petroleum of light specific gravity. Mr. Richardson indeed considers that the engineer should have the power of running into the grate any kind of oil which he thinks proper, either for cleaning the wicks or for the purpose of obtaining extra power.

“By the experiments which he has carried out at Woolwich, Mr. Richardson has satisfactorily demonstrated that petroleum can, for short periods at least, be successfully burned under a steam boiler, and the question whether it can be practically employed as a fuel for steam vessels appears to us to depend principally upon commercial considerations. The advantages claimed for petroleum are, principally, the facilities which it affords for compact stowage, its high evaporative power, the ease with which a boiler using it can be fired, and the certainty of the results obtained. In opposition to these advantages is placed the cost of the material. For vessels sailing from this country, the American petroleum would be rarely employed on account of its high price—the shale oil would be used, notwithstanding its inferior evaporative power. This oil will probably soon be procurable at from £5 to £6 per ton. If we take it at £5 10s. per ton, and its evaporative power as only one-and-a-half times greater than that of coal, its cost, compared with that of the latter fuel would, in the case of a steamer using say 900 tons of coal per voyage, be as follows:—

600 tons shale oil (= 900 tons coal) at £5 10s.,	£3,300
Subtract sum due to freight space saved = 300 tons at £4 10s.,	1,350
	£1,950

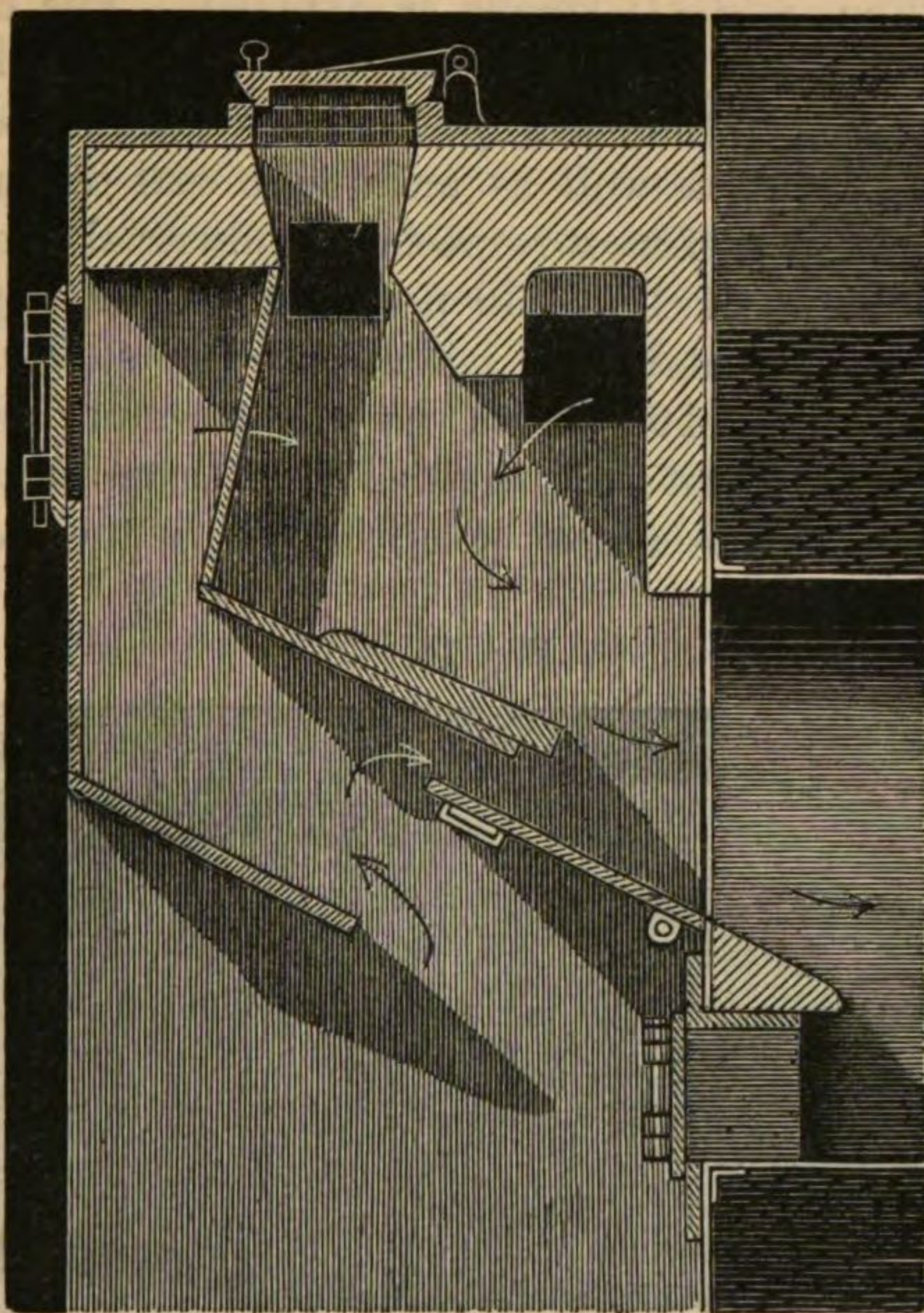
The cost of the 900 tons of coal, at 15s. per ton, would be £675, and in this case, therefore, the balance against the petroleum would be £1,275. In the case of vessels on Indian stations it would be different. In India the supply of coal is small, and that exported from England costs upwards of £4 per ton; on the other hand, there are abundant supplies of petroleum, the Rangoon wells alone being 520 in number, and supplying 400,000 hogsheads annually. The petroleum could therefore be probably

loaded on board at a price very little exceeding that of coal, and the saving in the freight space would therefore leave a large balance in favour of the petroleum. It is, however, for war vessels that petroleum fuel is likely to prove most useful. The fact of a certain weight of petroleum enabling them to steam from one-and-a-half times to twice the number of hours that they could do with the same weight of coal, is sometimes of far greater importance than any question of expense. On the other hand, if the same steaming power is retained, the saving in the weight of the fuel will enable them to carry heavier ordnance and armour, and altogether it seems probable that petroleum may eventually be used in such vessels with success. The greatest credit is due to Mr. Richardson for the patience and perseverance with which he has pursued his past experiments, and we hope that in the course of his future ones he may obtain even still more favourable results." A paper on the furnace employed by Mr. Richardson, and on various results of its use, will be found under Section Second of this present Division.

SECTION SECOND.—FURNACES.

36. *Wilson's Boiler Furnace.*—"We presented in a recent number," says "Engineering," "a section of Mr. E. B. Wilson's puddling furnace, as now in use with much success at the Milton Ironworks, near Barnsley. We now give a section, Fig. 15, of the same general arrangement of the inclined dead plates, as applied to the steam boilers at the works. The direction of the currents of air is shown by the arrows, a portion entering opposite the centre of the main flue, while the rest goes in through a pierced plate within the door on the extreme left, this plate being shown in full section, although it is really perforated with numerous openings. The slack coal is fed through the door at the top, and falls at nearly the slope corresponding to the shadows in our illustration. The poorest slack is used—there is no stoking, no production of smoke, and but very little refuse descends into the ash-pit at the bottom of the flue. As we stated in our former notice, Messrs. Dawes are making a general alteration of all their furnaces to Mr. Wilson's plan."

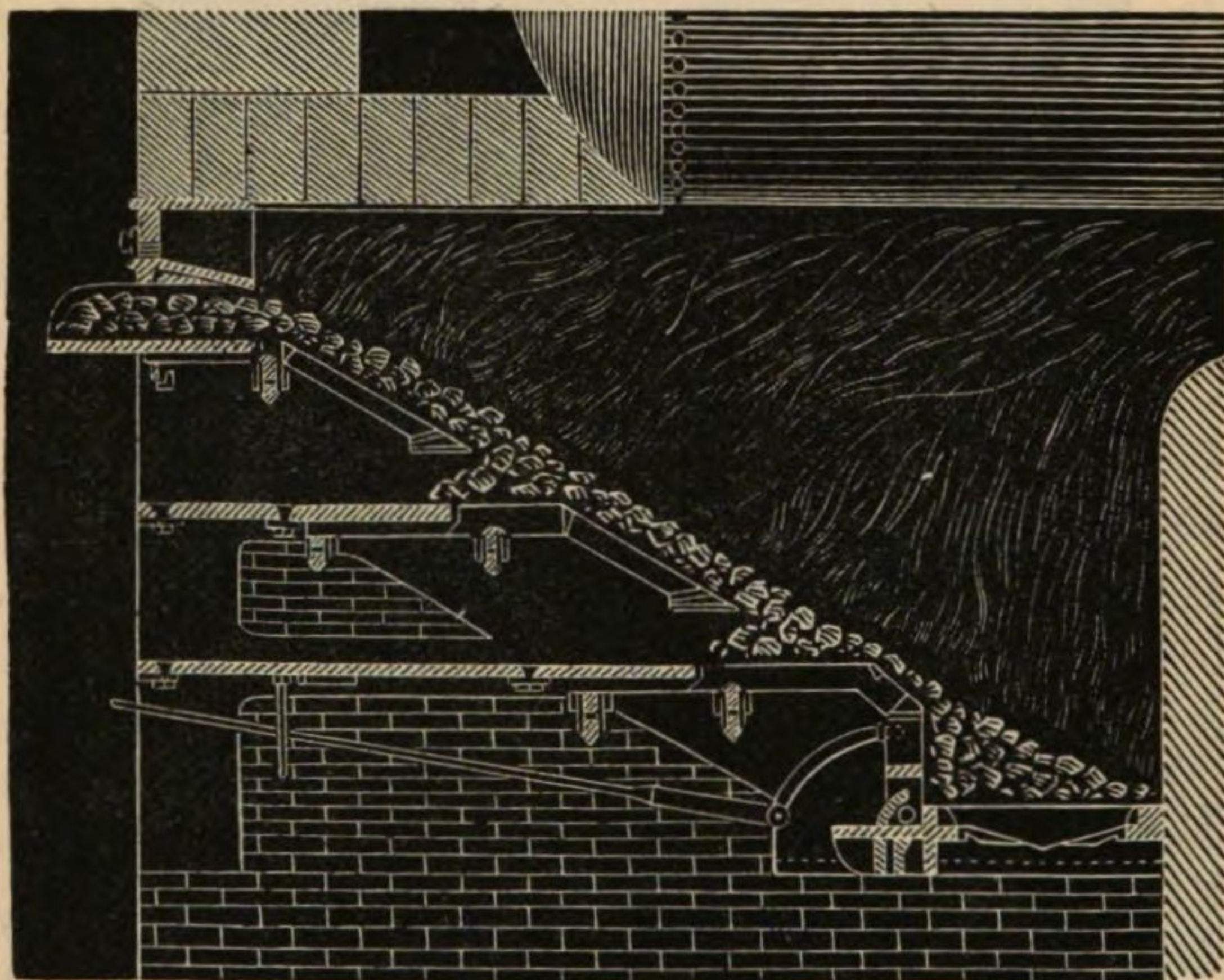
Fig. 15.



37. *Improved Grate for Steam Boilers.*—"The engraving (fig. 16) is a representation of a new grate for steam boilers and other purposes, recently invented by Eugen Langen, of Cologne, Prussia. We are informed that this grate is now preferred to all others on the continent of Europe, and that its peculiar characteristics are founded upon the happiest application of the theory of combustion. With this grate the fresh coal is not thrown upon the burning coal, but laid under it on an inclined plane formed by three tiers or steps. By this arrangement the fire is never cooled, but is always uniform, and the grate-bars are never overheated. It is also asserted that heat commonly radiated is taken up by the fresh fuel, drying and fitting it for burning; all dampness therein is evaporated without any loss of heat in front, and has to pass as steam through the burning surface where it is decomposed into its elements. And further, that all gases emanating

from the fresh fuel have to pass through the burning coal, where they are ignited, and all smoke is avoided. The construction of this grate allows it to be used for any kind of fuel—sawdust, shavings, bagasse, cotton seed, peat, brown coal, wood, coal dust mixed with coal tar, as well as anthracite coal of suitable size. Numerous certificates of most respectable industrial establishments confirm an economy of 18 to 30 per cent. of coal, a perfect consumption of smoke, and easy labour for the stoker. The annexed drawing, Fig. 16, shows its construction, which is an inclined plane of about 28° , divided into three parts in regard to the feeding and the access of air. We believe we recognise

Fig. 16.



therein the principal cause of its efficacy. Coal is composed of solid carbon (coke) and hydrocarbons (gas). The latter are driven off on a grate exactly as in a retort, and rise, mixed with carbonic oxide, carbonic acid, nitrogen, and perhaps some unconsumed air. The chemical proportions of the hydrocarbons tell us that they demand for complete combustion much more air than the solid carbon, and if this shall be drawn exclusively from the lowest part of the fire, through a plain grate, it will at times be either insufficient or such a rapid draft must be created as will drive

off the unconsumed gases altogether, or in part, and cool the fire more than desirable. Hence practical experience has always proved that the access of a limited and divided quantity of fresh air into the fire-box, above the principal mass of coal, favours combustion and increases the effect of the fire. This is obtained by this grate in the most simple and efficacious way. Any gas or carbonic oxide leaving the coal of one tier, or the last principal fire-grate, meets the air entering by the next tier, and principally that by the highest, or the two front openings, which can be opened more or less, and which intermixes with the unconsumed gases over the whole width of the fire-box, multiplying their contact, from which a more complete and intense combustion must result, and this principally directly under the object upon which the heat shall act. The construction and dimensions of this grate can and probably must be modified, according to the fuel to be used, but its effect must always be the same."—*Scientific American*.

37. *Siemens' Regenerative Furnace*.—In Division Second, Section Second, of our volume of last year, we described and illustrated the general principles and arrangement of this most important invention. It will interest our readers to gather from the following paragraph from "Engineering," how rapidly the principle is extending, and to most important applications in the arts:—"Mr. Siemens has lately established a steel-melting furnace, upon his own account, at Birmingham, which is working with a degree of success hitherto unknown or even believed by the Sheffield steel-converters to be possible. We need hardly say that he employs his well-known regenerative furnace. One of these heats fourteen melting pots and a muffle, each pot averaging 45 lb. of mild steel. There are six casts every twenty-four hours, so that the daily production is 3,780 lb. One gas-producer is in use, and the consumption of small coal, at 6s. a ton, is $1\frac{1}{2}$ ton per day, or about 18 cwt. only per ton of steel. To do the same work under the system of heating pursued in Sheffield, $3\frac{1}{2}$ tons of coke at 25s. per ton are required, the saving being thus upwards of £4 per ton for fuel alone.

"The fire-clay pots, moreover, stand six heats, or a full twenty-four hours' work, instead of three only, as in the ordinary furnaces.

"Mr. Siemens believes this to be the most important applica-

tion yet made of the principle of his regenerative furnace. It is already in extensive use, however, for reheating steel, and for various purposes, in large iron and Bessemer steelworks, as at Barrow-in-Furness, Crewe, the Mersey Steel Works, Messrs. Charles Cammell's, &c.

"At the Mersey Steel Works, at Liverpool, the gas-producers were excavated in the solid red sandstone, which cost 4s. a yard cube for excavation and removal. The whole cost of the furnaces, which would ordinarily be about £1,500, was carried therefore to nearly £2,500. But we believe that the yearly saving effected by these furnaces is far more than would repay their whole cost. They are making 50 tons of iron a-day, or (say) 15,000 tons a-year, and are saving $6\frac{3}{4}$ cwt. of coal per ton of iron, the coal being worth 10s. per ton. There is a further saving of the iron itself, which Colonel Clay estimates at three per cent., equal to 450 tons a-year, worth at least £6 per ton, or £2,700. The saving in coal amounts to nearly as much more.

"Mr. Sacré, of the Manchester, Sheffield, and Lincolnshire Railway, has had two of Mr. Siemens' furnaces at work at Gorton, since October last. In heating rail piles of 8 cwt., it is found that but 4 cwt. 1 qr. 5 lb. of slack, worth 5s. 6d. per ton, is used per ton of iron, while the consumption of coal, worth 10s. per ton, has been 7 cwt. per ton of iron in the ordinary furnaces previously employed.

"At Messrs. Johnson and Nephew's, the extensive wire manufacturers at Manchester, who have one regenerative furnace at work and another going up, $1\frac{1}{8}$ in. square rods are heated with a loss of but 2 per cent. of iron.

"In this class of furnaces the whole of the fuel is burnt in the gaseous form, the gas being mixed with highly heated air, coming in through a mass of brickwork previously heated by the waste heat or escaping products of combustion of the furnace itself. There are two of these masses of brickwork, or regenerators, the waste heat being let out alternately by means of valves, first through the one and then through the other, the valves being changed at intervals of greater or less time according to the size of furnace, quantity of fuel burnt, and heat required. While the waste heat is going out through one regenerator, the air is coming

in through the other, the gas being thus cooled progressively, by giving up its heat to the brickwork, while the air is as progressively heated. The final temperature of the escaping products of combustion at the tail of the brick-work regenerator is thus brought down to a very low point.

"The slack coal is distilled into gases as follows; taking the gaseous volume as it leaves the producer and enters the furnace:—27 per cent. of carbonic oxide, 10 per cent. of hydrogen, 4 per cent. of carbonic acid, 8 per cent. of bicarburetted hydrogen, 5 of tar and ammoniacal vapour, while the rest is nitrogen."

39. *Richardson's Petroleum Furnace.*—The following is an article alluded to in a previous paragraph in last section. We are indebted for it to the *Mechanic's Magazine*. The reader interested in the subject will find in the same magazine, under date September 14th, 1866, another article on the subject with drawings of the furnace here described:—"The important discoveries of petroleum which have taken place of late years in various parts of the world have naturally led to an examination into the methods most suitable for turning to account its heat and light giving properties. It is a material which has afforded—and will continue to afford—room for wide research, and ample field wherein the genius of invention may exercise itself. The processes of obtaining the oil from the rock, of purifying it for the market, and of utilising it as a source of light, have each in their turn been discussed in our columns. But there is another economical application of which it is susceptible, another purpose for which it appears to be pre-eminently adapted, and that is for raising steam. In other words, it would seem to be the most perfect substitute for coal, for steam purposes, that has as yet been met with. Its economic application at a time like the present, when there are such fears for our coal supply, will be hailed with satisfaction. For a long time past, an occasional note in our miscellaneous columns has apprised our readers that Mr. C. J. Richardson has been carrying on a series of important experiments for utilising petroleum as a steam fuel at Woolwich dockyard. These experiments were conducted upon the principles advocated by Mr. Richardson for burning mineral oil as a fuel for steamships and steam engines, and have recently been concluded, and their termination has shown them to be a decided success. Ten pounds

of water is the highest quantity that has ever been evaporated per pound of the best steam coals; upwards of 18 lb. of water has now been evaporated continuously, and with little or no smoke, for many hours, by oil from the celebrated Torbane hill or Boghead mineral. The trials with other rock oils, though not reaching quite so high a figure, have been such as to prove the superiority of mineral oil over coal, and the perfect capability of maintaining the strongest fire without the slightest cessation or diminution of its intensity until the complete exhaustion of the store of fuel. These trials have extended over a long period, during which Mr. Richardson has made many improvements in the construction of his furnace, which have been the result of watchfulness and observation. Although the results above given are sufficiently satisfactory for all practical purposes, and indicate the superiority of petroleum, when properly burned, over coal, it is possible that even a higher figure might have been reached had not a leakage of oil occurred at the back of the boiler.

“ With regard to the petroleum furnace itself, it may be simply described as having four fire-places, of wrought-iron, each 4 ft. 3 in. in length, 10 in. in width, and 1 ft. in height. At the back of each of these is a firebox 2 ft. 3 in. high, 9 in. wide, and 4 ft. 5 in. long. This firebox is open in the lower part, but is provided with a flat door. The boiler was originally made for burning petroleum and the shale oils alone. All the early trials made by Mr. Richardson last year were unsatisfactory. Petroleum burned in a confined space produces a large amount of smoke, and in those experiments any down draught, any irregularity in feeding or in the supply of air produced soot in large quantities. This state of things was decidedly inimical to the interests of the system, and of course was not to be tolerated, so Mr. Richardson set about devising a remedy. This he effected by fitting up a series of steam pipes, by which he applied steam, and so got rid of the smoke nuisance, much in the same way as has been done in coal furnaces. Mr. Richardson's idea was to superheat the steam, to decompose and burn it along with the petroleum vapour. This has been attempted by the Americans, Mr. G. Hill's process for the purpose having been experimented upon by Dr. Fisher of Newhaven. The petroleum was vapourised in a close box, steam being mixed with the vapour, and the vapour burned as it

issued from batwing burners. By this method Dr. Fisher burned petroleum several times under a small boiler, and measured the water evaporated. The steam was generated under a pressure of 40 lb. to the square inch, and hence from a temperature of 268 deg. After making proper allowance for the heating of the water, the results were 7.81 lb. of water at 268 deg. converted into steam by 1 lb. of petroleum—an extremely poor result. This system is now known as Stevens's, and was recently tried in New York by Mr. Julius W. Adams, for the Petroleum Light Company, and was attended with excellent results for the short time over which the experiment extended, which, however, was only one hour. A similar attempt to reduce the theory of petroleum furnaces to practice was made by Messrs. William Sim and Arthur Barff, of Glasgow, previously to the commencement of Mr. Richardson's experiments, the results of which are given by Mr. St. John V. Day, C.E. The petroleum or other hydrocarbon is here first converted into a permanent gas in the furnace of the boiler or heat recipient, a small quantity of coal being primarily used for effecting this change of condition. The gas is supplied with an amount of hydrogen which mixes with the carbon in the best proportion for burning, and the mixture is thus admitted into an atmosphere of oxygen, through which it is carried in jets or long lines of flame against the absorbent surface and tubes of the boiler. Additional hydrogen is obtained by decomposing a small quantity of water in the same vessel wherein the oil is vapourised. The proportion of oxygen thus liberated unites with a portion of the carbon and forms carbonic oxide. Mr. Day describes this system of mixing the vapour of water with that of the fuel as being the only way in which petroleum can be burnt with economy, and without the production of smoke, and we think he is quite right. However startling the law, that as much heat is required for the decomposition of water as is evolved by subsequent decomposition, it is quite certain that, used as an auxiliary to petroleum or any other hydrocarbon, steam causes the oil to be completely burnt, raises the temperature or evaporating power of the boiler from 60 to 80 per cent., and creates a smokeless flame.

“When Mr. Richardson's boiler was burning the American petroleum the effect of turning on the steam was certainly aston-

ishing; before the hand was off the steam cock the flame had flashed into quadruple its former size, all smoke instantly disappeared, and a brilliant yellow active flame completely filled the fireplace, firebox, and tube. The boiler was no longer large enough to contain the flame; instead of four fireplaces being lighted, only two were required. With one fire-place and a full jet of steam $\frac{3}{8}$ in. in diameter, the powerful experimental coal boiler of the Woolwich yard was beaten, although it has a fireplace containing 62 cubic feet of space. When two fire-places of the petroleum boiler were lighted it was found that the jets could only be turned one-third on, and no more than $8\frac{1}{2}$ lb. of oil was burnt per foot super of grate surface per hour. The steam was very slightly superheated and was at 10 lb. pressure. By means of this grate a ship going round the world could use either natural or artificial hydrocarbon, or even the residuum. The object of manufacturers at present is to make the oil of as light a specific gravity as possible, but there are shales which will yield crude oil of a heavy gravity, unfit for refining, but which would answer the purpose of fuel admirably, especially if used for land engines. For ships the oil could be stowed in the lowest part of the vessel, and taken up in a continual stream, by means of a syphon pipe, to the boilers. A great deal of time and labour are saved in stoking with petroleum; there is no opening of furnace doors for lighting or extinguishing the fires; by simply turning off the petroleum the fire is soon extinguished by the steam. If a boiler had three fireplaces, two could be put out, and the other kept at low combustion; on the order being given the oil would be turned on, and as soon as it began to vapourise all would be in flame. Petroleum makes no cinder or ash, but coke forms on the surface of the grate; this coke is indestructible and porous, and makes a capital top surface. A continuous fire can be kept up without the slightest cessation for any length of time, and to this is probably due the fact that 18.02 lb. of water were evaporated per 1 lb. of oil, as it had not been done in previous experiments. These experiments have shown the working of petroleum furnaces to be a most simple matter, and have established the fact that a gaseous fire is as easily managed as a gaselier light. The application of the principle to existing boilers which have water space beneath the

grate is very easily accomplished, involving no other alteration than a smaller smoke pipe.

"The success of an invention depends mainly upon its simplicity and efficiency, its adaptability to existing circumstances, and its economy in working over other methods for attaining the same end. By this standard, too, must its merits be measured; and as far as regards the first conditions named, Mr. Richardson's petroleum boiler appears to leave nothing to be desired. It is simple and efficient, and is well adapted for certain types of boilers with a scarcely appreciable amount of alteration, and other types may be made available at a very moderate cost. But the last and most important condition of economy in working at once opens up the question of the precise economic value of this fuel in comparison with coal. Having attained the ultimate economy in working, the question resolves itself into one of a purely commercial character, which must be determined by the price at which the oil can be delivered to the consumer. At present—notwithstanding the disproportion between the amount of each fuel required to produce a given effect—economy would still remain on the side of coal were ordinary petroleum used. But here it is important to draw the distinction between petroleum proper and the British shale oils and the heavy residuum of petroleum. The British shale oils can be had at a cost of from £7 to £8 per ton, and the residuum at from £3 to £4 per ton. Heavy crude oils have been selling at Mold within the last few weeks at £5 per ton. The residuum might do for land engines, and the crude oils, which are obtainable all the world over, for marine boilers. Where the beneficial effects of the petroleum boiler will be felt is in ships on long voyages, and the price of coal a thousand miles from England must be the basis upon which commercial calculations must rest. The price of petroleum, however, is much less than it was a year since, and with the constant discoveries that are being made, the market may still continue to fall until a point is reached which shall establish petroleum generally as an economical as well as an efficient substitute for coal. With regard to other advantages, there can be no question that great superiority rests with petroleum. These advantages, which Mr. Richardson has succeeded in perfectly developing, may be thus summed up:—Rapidly in raising steam, reduction in the dimen-

sions of boiler and furnace, continuous firing, freedom from smoke, cinder, ash, or other refuse, power of instantly commanding a forced fire without a forced draught, and a reduction in the staff of coalers, stokers, &c. By feeding the fuel through a pipe into the furnace, and thus effecting continuous firing, the loss of heat occasioned in coal furnaces at every fresh supply is avoided. The freedom from refuse, which with coal amounts to some 16 per cent. of the whole amount, is important, and saves all the inconvenience attendant upon raising clinkers and ash from the furnace-room of ships. Still more important is it at sea to be able to command a forced fire on the instant; this with petroleum is accomplished with ease and facility, whilst the stowage-room required for petroleum is considerably less than that occupied by coal."

40. *Utilization of Waste Gases from Blast Furnaces.*—In close connection with the economization of fuel in our steam engine and other furnaces is the utilization of the waste gases produced in blast furnaces. Much as has been done in this department, much more remains to be done. The following remarks from an article in "Engineering" will be read with interest:—"The advantages attendant upon the utilization of the waste gases from blast furnaces is now very generally acknowledged, it being found that not only is the fuel for the steam boilers and the hot-blast stoves saved, but that the cost of repairing these accessories is reduced when they are heated by waste gas, and that they are maintained at a more even temperature. There is also a considerable saving effected in wages, and the working of the furnaces themselves is improved, there being greater regularity as to the quality of the iron made.

"For taking off the waste gas, two plans have been adopted, the one being the 'close-topped' and the other the 'open-topped' system. In the ordinary close-topped furnaces the throat is partly arched over and surmounted by a species of cast-iron hopper, the central opening of which is closed by an inverted cone of cast iron. The charge is placed in the hopper around the cone, and the latter, being slung by chains, can be lowered at pleasure so as to admit the charge into the furnace. The gas is taken off by a passage leading from the arched part of the throat. Several objections have been raised to the 'close-topped' arrangement,

and amongst them, that it prevents the warming and drying of the newly supplied materials until they have descended some distance into the furnace. It has also been urged that there is less chance of detecting irregularities in the feeding in the close-topped than in the open-topped system, and that in the former the pressure of the blast causes more dust to be carried into the gas-pipes than finds its way there when the open top is used.

"In the open-topped furnaces the gas is sometimes taken off by side openings and sometimes by a central tube carried down for some distance below the mouth, this latter plan having been used, amongst other places, at Barrow and at the Grosmont Iron Works. At the latter place the arrangement consists of a wrought-iron tube 5 ft. in diameter, extending about 5 ft. down the throat of the furnace, and lined and cased with firebrick 6 in. thick. The tube is supported by a dome built in the throat of the furnace, and carried by six buttresses springing from the sides, the spaces between these buttresses being available for charging. The opening in the centre of the dome admits the gas into the tube, from which it is led off to the boilers, hot-blast stoves, &c., by a wrought-iron gas-main. The necessary exhaustion for drawing off the gas is in this case obtained by a chimney-stack 180 ft. high; but in some instances, where the gas has been taken from open-topped furnaces, the draught of a chimney has been assisted by flues.

"The plan of drawing off the waste gas by means of a side opening just below the mouth was applied to an open-topped furnace at Wasseraufingen, in Wurtemberg, as long ago as December, 1832, and since that date many modifications have been brought into use. Amongst others there is that introduced by Mr. George Addenbrooke, and applied by him to his furnaces at the Rough Hay Iron Works, Darlaston. This plan, which has been found to answer well, consists in replacing the firebrick lining of the throat of the furnace, for a certain depth, by a set of castings having openings formed in them through which the gases are drawn off into an annular flue formed around the head of the furnace. The fact of the gas passages being formed of cast iron enables the openings to be made so wide that the necessary area can be obtained for the free passage of the gas without the depth of the opening being more than 15 in.; and they therefore need

not be placed more than 5 ft. below the top of the throat, as that depth will give a sufficient quantity of fuel above them. The passages are inclined upwards, so as to prevent, as much as possible, dust being carried over with the gas, and their openings into the annular flue are considerably above the floor of the latter, so that a sort of pocket is formed, in which any particles which are carried over may settle, provision being made for their removal. In the case of the Rough Hay furnaces, there are fifteen gas openings round the neck, each $23\frac{1}{2}$ in. wide by $11\frac{1}{2}$ in. high, their area being thus 270 square inches each, or 4,050 square inches altogether. The annular flue is 4 ft. 3 in. high to the crown of the arched top, and 3 ft. wide, and the descending gas main is 4 ft. 6 in. in diameter. At the junction of the gas main with the branch leading from the annular flue a gas valve is introduced, this consisting of a disc valve which can be lowered so as to rest upon the top of the descending gas main and close it. This valve is closed, if by chance the materials in the furnace sink below the gas openings, and it is also used to regulate the amount of gas drawn off, so that in regular working some proportion of the gas shall always be burnt at the mouth of the furnace. The exhaustion is obtained by means of a chimney 160 ft. high, and 10 ft. in diameter inside throughout; the main flues leading to it are 4 ft. 6 in. wide, and 5 ft. high to the crown of the arch. In the furnace first fitted on the above plan in 1864, the plates in which the gas openings were formed were only 2 in. thick, but, notwithstanding this, they lasted upwards of twelve months. The castings now applied are 12 in. thick, and as they are flush with the inside of the furnace, it is expected that they will last many years."

SECTION THIRD.—SMOKE PREVENTION OR CONSUMPTION.

41. *Smoke*.—Under this title an article is given in the "Engineer," which we here give. It refers principally to the operation of the Act for enforcing the consumption of smoke. "That the prevention of smoke, in any furnace whatsoever, is a mere question of scientific adaptation, of a little extra expense in the first instance, and of a little extra continuous care, may be looked upon as an acknowledged truth needing no more proof than what

has been afforded by long experience. That a certain saving in fuel can be frequently effected by preventing the development of smoke is equally a matter of experience. On the other hand, we have the visible and tangible evidence of the intensely murky state of our manufacturing cities to show that these truths are practically disregarded. This is universally acknowledged to be an enormous sanitary and commercial evil, affecting the death-rate of our manufacturing districts and accelerating the time when England will be without coal, and we cannot help ascribing its existence to the inertia and ignorance of the great mass of our manufacturers. Acknowledging the fact that, in many cases, the hurry of competition does and must prevent this class from giving an attention to the matter in hand that would lead to reform, the unimpassioned observer must come to the conclusion that the root of the evil is to be sought in some of the many administrative shortcomings of what is termed self-government. That this is indeed the case must be clear to any reader of the late correspondence, between the Home-office and the municipalities of our great cities, called forth by the last debate in the House of Commons on the smoke nuisance.

On the 12th of last March the Home-office wrote to the mayors of Birmingham, Derby, Huddersfield, Leeds, Leicester, Liverpool, Manchester, Newcastle-on-Tyne, Sheffield, Sunderland, Swansea, Wolverhampton, Worcester, and to the stipendiary magistrate of the Potteries district, at Stoke-on-Trent, asking these gentlemen to state what enactments against smoke were in force in these several places; whether the enactments extended to all 'branches of industry;' how long had they been in force; to state the means taken for improving the law; the resulting number of convictions in each successive year; and lastly, the effect produced by 'these enactments in diminishing the nuisance?' The municipalities of all these towns have replied, with the single exception of the authorities of sulphurous Swansea. According to the answers of the majority of the municipalities, the legal bases for proceedings against the smoke nuisance is afforded by the 108th section of 'The Towns Improvement Clauses Act, 1847' (10 & 11 Vict., c. 34), which has, in most of the large towns, been incorporated without much change into the local 'Improvement Acts,' passed for many places. This is the case with the

Birmingham Local Act of 1851 ; the Leeds Act (19 & 21 Vict., c. 115) ; The Liverpool Sanitary Amendment Act, 1854 ; the Manchester Local Act of 1851—a local Act passed in 1844, was previously in force in Manchester ; the Newcastle-upon-Tyne Improvement Act, 1853 ; the Borough of Sunderland Act, 1851 ; and the local Act of Wolverhampton, 1853. At Derby, Huddersfield, Leicester, Sheffield, Stoke-on-Trent, the 1847 'Towns Improvement Act' is in force in its entirety. Now the 108th section of this Act is, as appears to us, exceedingly ambiguous—at any rate, it may be so twisted as to exempt some of the most notoriously smoky furnaces—though, on the other hand, it might be made a formidable weapon against the smoke nuisance if wielded by a determined bench of magistrates. To show how pliable the old Act is, though apparently so stringent, it must be observed that at Wolverhampton, the Local Government Act, of 1858, is in force, with all its exemptions, though the Local Improvement Act incorporates the previous Towns Improvement Act. At Worcester, the Towns Improvement Clauses Act of 1847 is incorporated with the Local Government Act of 1858—the Public Health Act of 1848 having been in operation there.

“At Huddersfield, Manchester, Newcastle, Stoke-on-Trent, Sunderland, Wolverhampton, and Worcester, the enactments are stated to extend to all ‘manufactures.’ At Derby are allowed the numerous exemptions under section 45 of the Local Government Act of 1858 ; and at Leicester and Sheffield the enactments bear upon steam furnaces only. At Leeds it is honestly confessed that several trades are practically exempt. From Liverpool the mayor writes that steamboats plying between that city and the Isle of Man have been held not to be within the law ; and puddling furnaces are also practically exempted by the proviso in the local Act, by which persons who have done their best to consume the smoke cannot be punished. Such is a brief account of the legislative hotchpotch which has been concocted in this practical country with the presumed intention of preventing a most deleterious and wasteful nuisance.

“At Birmingham the enactments are stated to have been in force since 1853 ; at Derby since 1860 ; Huddersfield since 1859 ; at Leeds and Newcastle-upon-Tyne since 1856. At Leicester the bye-laws against smoke have been in force since 1857

and 1859. The first information, according to 'The Liverpool Sanitary Amendment Act' of 1854, was laid in June, 1855. The two local Manchester Acts of 1844 and 1851 have been in force since those dates—with what result any one knows who has lived in Manchester. The clause of the 1853 local 'Improvement Act' of Newcastle against smoke—a repetition of that in the general Towns Improvement Act of 1847—was only acted upon in September, 1856. The bye-laws of Sheffield were passed in 1854, but the smoke clause in the 1847 Towns Improvement Act has only been in force since September, 1864. Though the Stoke-on-Trent authorities say that the enactments bear 'on all' furnaces, they then make the contradictory statement that the enactments have only been 'in force since the adoption of the Local Government Act.'

"The ordinary means supposed to be taken for enforcing the law are proceedings before justices on information of the inspectors of nuisances, when the offender is liable, according to the 1847 Act, to a fine of forty shillings. This is stated to be done at Birmingham, Derby, Leicester, Newcastle, Sheffield, and Sunderland. At Huddersfield a more paternal method is adopted, and observations are taken by inspectors of 'dense' and 'moderate' smoke, and since 1860 prizes have been given to stokers who, by attention to their furnaces, caused least smoke. At Leeds, a special committee of the town council is appointed to carry out the law; at Liverpool a mechanical engineer and his assistant are exclusively employed in looking after smoke nuisances, and attending before justices to support informations. At Manchester the nuisance department of the corporation inquire, and on finding an infringement of the law inflict a fine, which is usually paid; if not, proceedings are taken before magistrates. The authorities of Stoke-on-Trent plainly confess that the law is a dead letter throughout the Pottery districts. At Sunderland the town council appears to have obtained promises of reform; and at Wolverhampton nothing at all has been done, though the subject has on several occasions occupied the attention of the town council. Worcester contains but few manufactories, and there have accordingly been only few complaints.

"The fairest test for the zeal of the corporations is evidently, other things being equal, the number of convictions. The great-

est number of convictions have thus taken place in the city of Liverpool. In the six months ending 1855 seventy-three persons were convicted in Liverpool. This appears to have had its effect for a couple of years. In 1859 eighty-four persons were fined, and only eleven the next year. In 1864 the number rose to 105, and in 1865 to not less than 142. At Birmingham the number of fines rose from three in 1854 to seventy-two in 1861, and then gradually fell to thirty in 1865. At Manchester no cases have been brought before the justices since 1857. At Sheffield rather more zeal has been shown. In 1855 there were fifty-nine convictions; in 1856, seventy. This number then fell to four in 1860, rising to seventy-four in 1865. At Leeds but few convictions have been made. An indirect effect of Sir W. G. Armstrong's inaugural address before the Newcastle meeting of the British Association (1863), in which he spoke so strongly about the waste of fuel, is perhaps perceptible in the twelve convictions at Newcastle during that year, though no information seems to have been laid during the two previous years, and only two fines have been levied in 1864 and in 1865. At Huddersfield, Stoke-on-Trent, Sunderland, and Wolverhampton, no proceedings have ever been taken.

“Then comes the important question as to the effect of these Acts of Parliament in diminishing the smoke nuisance, or rather, more properly speaking, the results of the mode in which these laws are actually administered. As the administrators themselves speak about the effect of their own work, it need scarcely be said that the accounts sent to the Home-office are mostly very favourable. From Birmingham we hear that the quantity of smoke has been diminished, as almost all furnaces or fire-places are fitted with some method for consuming the smoke produced. At Liverpool it appears that though the smoke nuisance is considerably diminished, things would be better if the fines were more uniform, as the highest fine is £5, however often the person may have offended. The Manchester authorities say that there has been a marked improvement—what Manchester must have been before this marked improvement it is difficult to say. The Sheffield letter is more ingenuous; it is observed that the smoke is to some extent diminished, but that manufacturers generally evince reluctance to comply with the bye-laws. The Huddersfield

authorities say that the average amount of dense smoke is 'reduced from $16\frac{1}{2}$ to $6\frac{1}{2}$,' and the Leicester people congratulate themselves in a similar way. Leeds, Derby, Sunderland, and Wolverhampton are not so contented. At Derby, from carelessness or other causes, the law is not so generally observed as it ought to be. At Leeds there is a difficulty in dealing with dyers, iron-manufacturers, and brick-makers, whom the law has hitherto failed to reach, and Sunderland and Wolverhampton give similar accounts.

"The first thing that will strike the reader is the important omission in Sir George Grey's letter in not requiring a statement of the coal annually burnt in each town within a given area. Some test as to the amount of soot in the air is also required, and it is not impossible that this test might be found in an average of a few analyses of the rainwater gathered in each city at given periods of the year." In the same Journal, under date June 15th, 1866, an article is given descriptive of Juckes's Smoke Preventing or Smoke Consuming Furnace,—we regret we have not space for the illustrations accompanying.

42. On the subject of *Smoke Prevention*, the well-known engineer, D. K. Clark, has written the following letter to the Editor of "Engineering:"—"I believe you have hit upon the solution of the problem of smoke prevention in the most general form, in recommending the preliminary conversion of fuel into combustible gas, prior to the formal admixture of air for combustion. The experience that has been gained with the gas furnaces attached to the regenerative system of Mr. Siemens, has proved that fuel can be completely burnt without discharging smoke, and also that it can be done with the greatest degree of economy. As Mr. Fairbairn very truly says, you must have a high temperature, air must be admitted above or beyond the fuel, it must be thoroughly mixed with the gases to be consumed, and the draught must be sufficient. These conditions are united in the greatest perfection in the gas furnace.

"There is plenty of evidence, it is true, that smoke may be consumed with an economical result in ordinary furnaces; but under what circumstances? Carefully studied firing, easy combustion, abundant boiler power, and no stress on the fuel. I do not now point to slow any more than to rapid combustion.

A Cornish boiler burns only 4 lb. of coal per hour on each square foot of firegrate, and an express locomotive engine burns twenty times as much; and they can both be made, with equal facility, to consume their smoke, and economically too. But, where boilers are short of steam, or, in other words, where more work is taken out of them than they are adapted for, the fire must be perpetually urged and the coals turned over, large volumes of combustible gases escape unconsumed, unless the firedoor is opened and plenty of air admitted: but then the pressure falls, and the engine loses speed. There are multitudes of plans for smoke-consumption; but the proprietors of furnaces are sick of them, by reason of the great expenses in most cases attending the application of them, their want of durability, the want of care of management, and the want of efficiency. I have seen hundreds of furnaces cured, but in the majority of instances no economy has been effected, except incidentally by enabling the proprietor to burn a cheaper class of fuel; and there can be no doubt that the professions of saving—in many cases 25 to 50 per cent.—made by nine out of ten smoke doctors, are utterly unsupported by experience.

“In the use of the gas furnace for industrial purposes, introduced into this country by Mr. Siemens, the French have set us a lesson. The fuel being, in the first place, converted into gas, increased facility is afforded for reducing the loss of heat by surplus air to the lowest practicable limit, and at the same time effecting that intimate mixture of the elements which is essential for complete combustion; thus, not only is the appearance of smoke prevented, but a decided saving of fuel is realized as against the ordinary system of burning unconverted coal on the common grate.

“Juckes’s furnace, by the way, is very efficient—probably as good as the Cornish boiler stoked in the Cornish style. But they both require plenty of room; moreover, you cannot by either method get up the high temperatures required in many situations.—I am, yours, obediently.”

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION
SECOND, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

Petroleum Fuel,—Engineering, July 13th.
Peat as a Fuel for Locomotives,—Mech. Mag., Nov. 9th.
The Smoke Nuisance,—Mech. Mag., Oct. 19th.
Coal Oil,—Engineer, June 22d.
Factory Smoke,—Civil Eng. and Arch. Journal, Nov.
Generating Heat,—Mech. Mag., Jan. 26th, p. 55, Illustrated.
Petroleum as Fuel,—Scientific American, p. 82, Illus.
Siemens' Regenerative Gas Furnaces, Mersey Steel and Iron Works,—
Engineering, Aug. 17th, p. 110, Illus.
Our Coal Supply,—Engineer, June 15th, p. 439.
The Derrylea Peat Works,—Engineer, March 30th, p. 231, Illus.
Bessemer's Puddling Furnace,—Engineer, Aug. 24th, p. 136, Illus.
Perkins's Steam Oven,—Engineering, April 6th, p. 215.

DIVISION THIRD.

STEAM ENGINES.

SECTION FIRST—STATIONARY ENGINES.

43. We cannot more appropriately, and, we believe, not more suggestively commence this important division of our work than by giving here an article under the title of "*Steam Engine Construction*," from "Engineering:"—"No one doubts the exact sciences, and there are many who prefer to believe that the science of steam engineering is as thoroughly established as that of mathematics. On the other hand are those who, knowing little of steam, but having large faith, are always declaiming that 'steam is in its infancy.' Now our knowledge of steam is, no doubt, gradually increasing, and yet we say this rather as a willing concession to the labours of so many painstaking philosophers who are constantly seeking to improve our knowledge, than from any conspicuous discovery, or ascertained truth, which has attended their later labours. It may be that we have had established

only lately the first and the second law of thermodynamics, but it is a little doubtful whether we have, in consequence, obtained a knowledge of steam giving us better results than we had attained before. There were Cornish engines, years ago, which worked with a consumption of coal of but 2 lb. per *effective* horse power exerted per hour. We may set this down as corresponding to about $1\frac{3}{4}$ lb. of coal per indicated horse power, the standard now commonly adopted. It has been asserted of certain engines, made within the last six or seven years, that they have worked down to $1\frac{1}{4}$ lb. of coal per indicated horse power per hour, but, supposing this to be the fact, we know that these engines worked with from 100 lb. to 130 lb. steam, and that they expanded this within a low pressure cylinder, working in connexion with a surface condenser. It is not, however, quite an assured truth that this result was ever obtained. All that we have seen authenticated by a responsible name was the certificate of a professor of engineering in a northern university, who once saw a steam vessel working for about an hour at this estimated rate. Most engineers will say that an hour's performance can go for but little. There is the difficulty of settling the question whether the coal remaining on the grate at the end of the trial be equal to that of the beginning, and, too, a very slight difference in the steam pressure might represent a comparatively large quantity of steam worked out of the water already heated in the boiler, and therefore not due to the evaporation during the time of the trial.

“All the theoretical means of economy have, however, been known for a long time, if not since the days of Watt. He understood and practised expansive working, and he was aware that high pressure steam permitted of a greater degree of expansion than low pressure steam, although, for practical reasons, he preferred the latter to the former. Trevithick and Woolf both set the example of high pressures, and Woolf left a specification upon record which proves that his notions of expansion were even beyond, and very greatly beyond, the truth. Evans, too, in America, worked up to pressures, in large pumping engines, of from 150 lb. to 220 lb., and after him were Jacob Perkins and Dr. Alban, who went much higher.

“Superheating was proposed many years ago, and the advantages

of keeping the steam dry have long been known. Indeed, the steam jacket and the thickly clothed cylinders of many of the older engines show how careful were the early engineers in this respect. Surface condensation was practically in use thirty years ago, but we do not refer to this for the purpose of placing it among the means of steam engine economy, except at sea, where it saves the water otherwise blown out of the boiler to prevent saturation with salt. Even here, the saving by surface condensers cannot, where one half of the water in the boilers is blown into the sea, be more, theoretically, than about one-seventh of the coal burnt when working with injection condensers. Practically, the tubes or flues of marine boilers, working salt water, become more or less incrustated with sulphate of lime, and this incrustation causes a further waste of heat.

“If there be any one of the theoretical means of economy in steam which was not employed by the earlier engineers, it must be high piston speed, although we are not so sure that even this is a recent innovation. Regulating the amount of expansive working by means of the governor was tried by Watt, it was patented by Richard Roberts in 1832, and it was long ago employed by Mr. Brownlee of Glasgow and by Mr. Petrie of Rochdale.

“We are inclined to believe that there are, proportionally, more good and economical engines working now than there were thirty or forty years ago, but this has been due chiefly to a moderate increase in the pressure of the steam, and to improved workmanship. If the sole object in improving an engine were to diminish the consumption of coal to, say, 2 lb. per indicated horse power, nearly every steam engineer of considerable practice could guarantee this result. But, somehow, the engines that accomplish this are not in great favour. It is idle to say that employers of steam power are insensible to their own interests, and do not value a saving of coal, which directly represents a definite saving of money. But they do consider as well the question of interest upon first cost, and the cost of attendance and oil, and especially of repairs. Suppose a manufacturer to obtain his coal at 8s. per ton, and that he works his engine at 100 indicated horse power for $57\frac{1}{2}$ hours a-week. The difference of 1 lb. of coal per indicated horse power would, in this case, represent a difference of £53 8s. per annum. Suppose, however, that the

engine which saves this sum costs £1,000 more to begin with. The saving is at once eaten up in interest. Many will say, 'But surely it does not take £1,000 extra to provide a steam jacket, or a superheater, or improved expansion gear, or even all of these together.' Perhaps not, but most of the improved engines are nevertheless costly. In the States, Mr. Corliss has built up a vast trade in improved engines, and he has done so by contracting, as Watt had to do in his time, to receive in payment only the value of the coal saved in a series of years. At least this was done in many cases at the commencement of Mr. Corliss's career. Mr. Douglas, of Kirkcaldy, N.B., is now making engines, much after the pattern, we believe, of that set up by Mr. Corliss himself at Messrs. A. Pirie and Son's paper mill at Stoneywood, Aberdeen, but we do not suppose that Mr. Douglas consents to receive the saving in fuel in payment for his work. We understand, however, that a Manchester firm manufacturing an improved form of engine offer to do this, and we mention the fact as one of interest to users of steam power.

"The manufacturer, seeking the best engine for his purpose, generally finds that the so-called improved forms are mostly in an experimental stage. No one has given us the commercial results of working them over a long period. We do not say this with any thought of decrying improvements, but because it is a fact. The saving in coal is one thing, but the manufacturer has to consider other points as well. If, he says, such or such an engine requires more careful attendance, or a specially skilled engineer, the question of increased wages comes in. If it have superheaters, or any considerable extra number of joints and wearing surfaces, there is the cost of repairs to look to, and it is not only their cost, but the interruption which they cause by the stoppage of large works is a far more weighty consideration. What has a manufacturer with a mill full of orders, and working 300 or 500 hands, to say to an engine which may fail him at some unlucky moment? With this dread of untried plans, or of those which have had but a partial adoption, he will be suspicious of the engine which has a superheater or a surface condenser, or which works at an uncommonly high speed.

"We know that there are those at work in the field of steam engine improvement who are striving to combine all the econo-

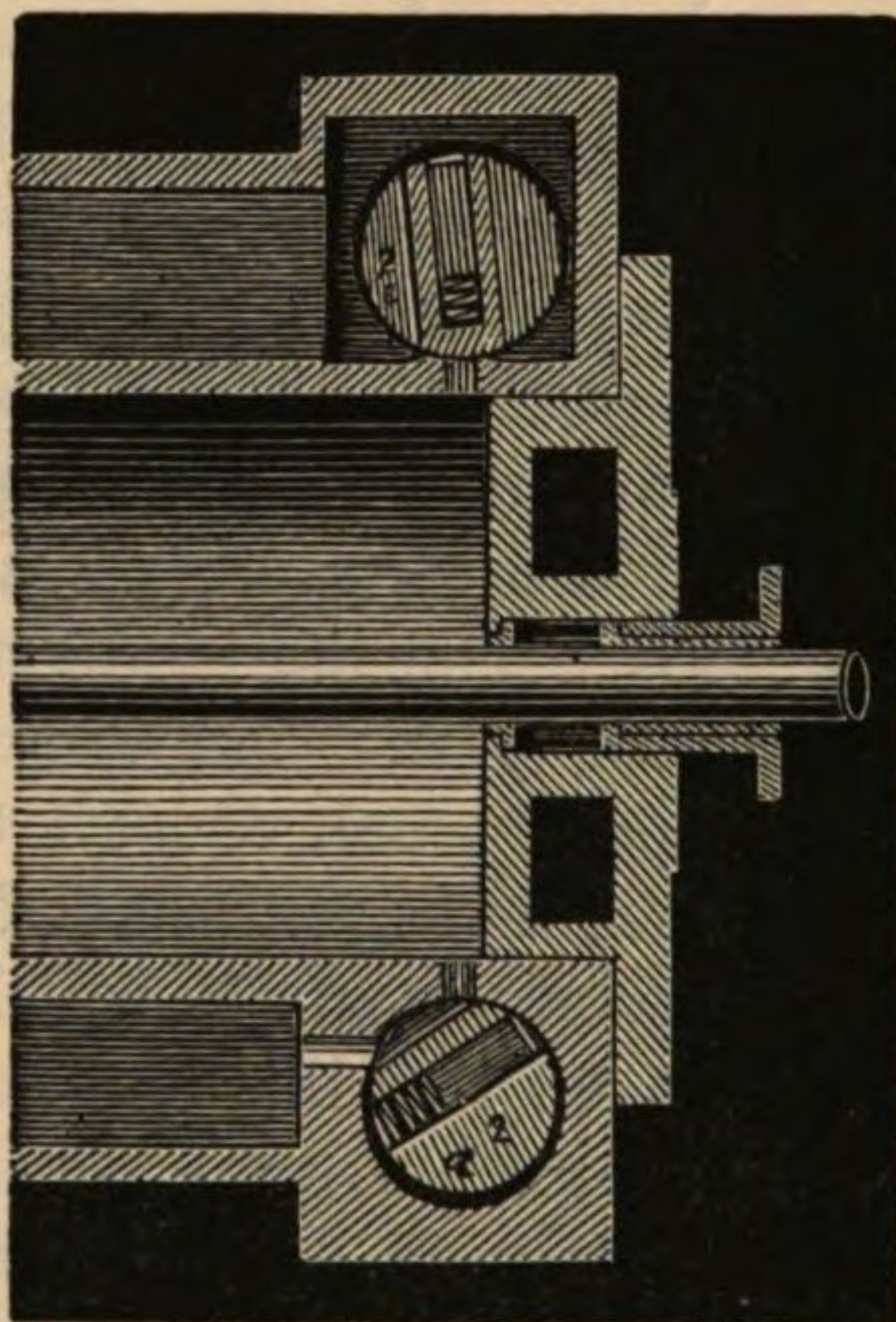
mical qualities desirable in steam engines, and we are disposed to believe that some of them have already attained great success. But there are but few—very few—which have given the public an opportunity of judging whether the improved engines are really and permanently successful or not. We could refer to one or two types of engines, of which a good deal has been heard, but of which, after some years of probation, no definite and satisfactory information has been made public. The obvious presumption is that the practice, thus far, has not been all that could be desired; but we offer no opinion of our own upon this point. We only mention the matter to show that a degree of uncertainty still attends the improved engines. Where steam of high pressure is required, there is a further uncertainty as to the boiler. We have not quite succeeded in perfecting a high pressure boiler for manufacturing purposes. The multitubular boiler is costly, and is liable to choking with scale. The Lancashire boiler, with two flues, cannot well be made small enough to be safe at very high pressures. We know, however, that Mr. Adamson has made $6\frac{1}{2}$ ft. boilers of Bessemer steel, which have worked at Messrs. Platt's, at Oldham, at 100 lb. per square inch. But we cannot think that millowners are quite prepared to follow up this practice. Steel, even yet is an uncertain material for boilers, especially for those parts exposed to the fire. The Harrison cast-iron boiler has proved a complete failure in this country, and thus we are still in a great measure dependent upon the single-flue Cornish, or the two-flue Lancashire boiler for generating steam. There are many other ingenious forms of boilers, but, although one hears of them, it is difficult to obtain authentic information as to their continued actual working.

“As for high piston speeds, we have little published and authenticated information as to what has been or is being done. Occasionally marine engines work, on trial trips, up to 500 ft. or more, but this is not maintained in ordinary working, and, as it is, every care has to be taken to prevent heating. For land engines it appears doubtful whether the high speeds often recommended have yet been attained with permanent success. If those who advocate a reform practice in steam engines, and who are actually practising what they profess, could but know how much mistrust is caused by their neglect (for we will not call it

inability) to give public information, establishing the correctness of their practice, they would soon speak out."

44. The following from "Engineering" is a brief description of the *Corliss Engine* alluded to in the previous paragraph:—"We give, fig. 17, a section of part of the cylinder of one of the

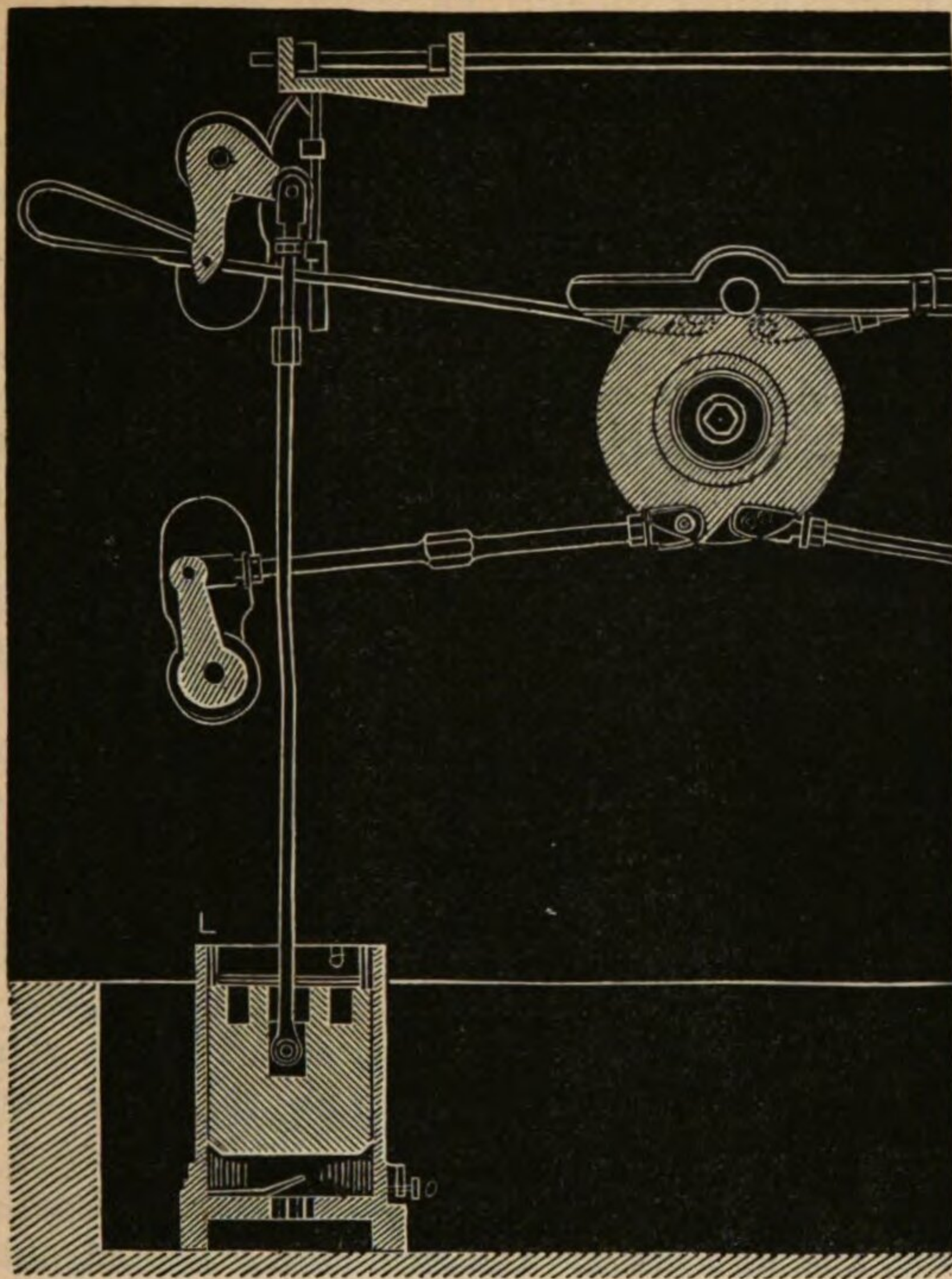
Fig. 17.



Corliss engines made in Prussia, and exhibited in the International Exhibition of 1862. There are separate steam and exhaust valves, one of each to each end of the cylinder, and instead of sliding, these valves vibrate upon circularly bored seats. Above is the steam pipe, and at the bottom the exhaust passage. Steam is entering the left-hand end of the cylinder, and the exhaust port is open at the opposite end.

"In the diagram the centres of the respective vibrating valve spindles are seen in the same relative positions. A large vibrating disc is moved to and fro by the eccentric hook engaging a pin, the disc moving upon a stud fixed upon the outside of the cylinder, midway of its length and height. Stud pins in the disc, which Mr. Corliss calls the 'wrist plate,' work the valves through rods or links. Short arms convey the requisite vibrating motion to the valve. The rods to the lower or exhaust valves are permanently connected to the wrist plate and valve arms.

Fig. 18.



For the steam valves, however, the ends of the valve links engage the studs in the valve arms by edge contact only, something like the action of the finger-nails if one on one hand be hooked against one on the other. These edges, perhaps $1\frac{1}{4}$ in. long, are upon pieces of steel, one of which is in the end of each valve link. The links act against the undersides of the pins in the valve arms, and the former are kept up only by light springs formed upon their ends, as shown, one end of each spring coming over and bearing upon the upper side of the pin. If the eccentric hook be moving from left to right, the left-hand steam valve link will pull the valve arm with it and open the valve, and an arm at right angles to the crank arm will lift the weight in the air-

cylinder or dash-pot below. It is evident, however, that with the slight edge contact by which the valve is opened, and with only a slight spring to keep the valve link up to its work, the latter may be very easily disconnected. This may therefore be effected by the governor. The horizontal rod at the top is connected to the governor, and slides to and fro with the variations in the speed. Connected to this rod are two inclined planes which move with it. Two vertical studs, held up by light springs, are pressed upon by the under surfaces of these inclines, and the lower ends of these studs, if the speed be greater than intended, will thus be pressed down against the valve links, and will force them down out of edge contact with the valve arms. The point in the stroke of the valve links, or, we will say in the stroke of the piston, at which disconnexion may be effected will be according to the speed. It cannot take place later than half stroke, but it may be at any earlier part of the stroke. The moment the disconnexion is effected, the valve, which moves freely as there is then the same pressure in the cylinder as in the valve chamber, is instantly closed by the weight in the air cylinder, which has the arrangement shown for checking the fall of the weight by cushioning near the bottom of the cylinder. Mr. Corliss varies the details of this gear in very many ways, but the general mode of moving the valves, and disengaging by interrupting the edge contact of the links, is the same. The gear may look complicated, but it wears well in many hundreds of Corliss engines in America and in Germany, and in a few even in Scotland. The advantages of the gear are a sudden opening of the valve, short steam ports, and little waste of steam, slight valve friction, and, above all, the most perfect regulation of the speed under varying loads by varying the expansion. Mr. Spencer has improved upon this gear so as to adapt it to quick-working Corliss engines, and, as we have mentioned in former numbers, the improved engines are coming into extensive use."

45. *Hall's Rotary Engine*.—The attempts to obtain a good working engine of this class, in which the power of steam gives directly a rotary motion, have been so numerous, and the failures so complete and disheartening, that they may almost come under the category of hopeless inventions. Yet there are those who believe

that we shall yet see a really good engine of this class. The following paper, read before the "British Association," by Mr. G. D. Hughes, is explanatory of another attempt to realize this hope. "Like the searchers for the philosopher's stone, or the students of perpetual motion, the advocates of rotary engines have pursued their object with untiring diligence from one generation to another, with this advantage, however, over the two former, that whilst they are impossible, the inventors of rotary motion have to a considerable extent been successful in their endeavours, and there seems to be no substantial reason why they should not ultimately attain their end. The vast improvements made in the construction of our engines and machines by the invention and perfection of new and improved tools, the great strides made in our knowledge of kindred sciences, and the constitution of the material world, have rendered easy of accomplishment what was before considered impossible ; and in the mechanical world we have numerous instances of this fact ; for instance, what kind of work would the Armstrong or Whitworth guns and rifles or the delicate and complicated lace machine of the present day have been, made with the tools and appliances in use forty years ago. Taking these circumstances into consideration, our enlarged knowledge, and increased facilities for producing improved constructions, I am strongly inclined to believe the difficulties hitherto presented will eventually be overcome, and that a good, durable, and efficient rotary engine will be an accomplished fact sooner or later. With these few remarks, I now beg to draw your attention to a rotary engine recently invented by Mr. W. Hall, of Nottingham, who, however, does not claim the whole as being original ; yet there appear to be some new features introduced, which have not been previously adopted, and, on the whole, it seems to promise a more successful result than any of its predecessors. This invention has not been the result of accident, or hit upon unexpectedly, but is the offspring of patient and laborious study and perseverance in pursuit of the object in view. The inventor has spent a large portion of his life in investigating the subject and in the making of numerous plans and models to accomplish his purpose, and so far has he succeeded in the present instance that, as far as the writer has had opportunities of judging, and from an experience of twenty-five years in occasional read-

ing and studying this matter, he believes it to be the best arrangement which has yet come under his notice, and one which fully deserves the careful attention of the scientific world.

"The inventor has now tested the arrangement for several years in various ways, and so far it has answered the best expectations formed of its efficiency, and he now only requires the opportunity to test it on a more extended scale. He believes fully to ensure its success from its occupying such a small compass and its general compactness of construction. He believes it would be peculiarly adapted for the propulsion of steam ships, for which from its form it seems specially adapted. The consumption of fuel during the various trials was most moderate, and the indicator diagrams taken under varying circumstances of load and speed compare favourably with any of our best engines on the reciprocating plan, whilst the great regularity with which it runs with quickly varying loads is very remarkable, but this may be accounted for by the manner devised for the admission and cutting off the steam so close to the cylinder. The engine was started last Saturday week and is now working very well, making 150 revolutions per minute with a boiler pressure of 60 lb. This engine has a cylinder 24 in. diameter and 30 in. long, the piston measures $18\frac{1}{4}$ in. diameter, being also the same length as the cylinder. Estimating the average pressure in the cylinder at 30 lb. per square inch during the whole of the revolutions, the engine drives about 65 indicator horse power. The cylinder is truly bored and faced at each end, with suitable covers for same also faced, through which the main driving shaft works, and which shaft is supported in each cover by a taper brass bush at each end, acting as journals, and capable of being adjusted to allow of wear. The piston is of the eccentric kind, and is made perfectly steamtight in contact with the circumference of the cylinder at the extreme of the throw by means of a metallic packing, kept tight to the face by steel springs similar to those used in the piston of the reciprocating engine. The ends of this piston are also made steamtight against the covers by means of an annular ring at each end, kept up to the face by the same means as the packing at the outer circumference. On the inlet steam-pipe is an equilibrium cut off valve, arranged so as to be worked by means of the graduated cam connected to the governor which

controls the admission of steam at each revolution in proportion to the load on the engine. This arrangement regulates the speed of the engine with the greatest accuracy under the most variable loads and with the least possible amount of steam required to do the work.

"The governor is placed horizontally on the main shaft, and by means of the spiral spring and a stop-collar at one end can be adjusted so as to vary the speed of the engine almost to any extent. An abutment slide follows the piston during its revolution in the cylinder, and it is through the opening or port in this slide that the steam is admitted into the cylinder. Another peculiarity in this abutment slide is an arrangement whereby the steam acting on the top forces this slide down, and keeps it in contact with the piston during the first half of the revolution, rising, however, again into the chamber as the piston approaches the end of its revolution ready for the re-admission of steam for the next stroke. The main shaft is of Bessemer steel, and the equilibrium valve spindle of the same material, whilst the cam is of chilled iron, so as to ensure durability in the working parts. The shaft can be made any length, and will give out the power of the engine, either at one or both ends, as may be required. The engine can either be used as a condensing or non-condensing one, and this principle can be applied equally well for air pumps to condensing engines or pumps for general purposes, and the engines and pumps may be arranged to work either way with equal facility and efficiency. If on farther trial the engine answers the expectations formed of it, the inventor believes the following advantages will be the result of its adoption:—First, saving in first cost over reciprocating engines under similar circumstances and of similar power of upwards of 30 per cent. Second, saving of power required to work and change the motion of the parts of the reciprocating engine. Third, compactness and portability, saving room, and expensive foundations and special adaptation for purposes of propulsion in steam vessels. Fourth, less working parts, and consequently less friction and wear, with less liability to get out of order and easy facility to get at and repair or replace any part which may become deranged. Fifth, steady and regular turning at high speeds, and consequent saving of intermediate gearing for high speed machinery and economy of work.

ing equal to the best engines on any other principle. Sixth, saving of steam contained in the ports usually let out with the exhaust steam in most engines at the end of each stroke. These engines can be arranged so as to work backward or forward with equal facility, and can be fixed to drive end-way as in driving a screw propeller, or cross-way to drive the paddle-wheels of steam vessels, or for any other purpose."

46. *Steam Engine Indicator*.—"Perhaps nothing connected with steam engineering of such acknowledged importance receives so little attention among builders and owners of steam engines. Its use to the constructing engineer is of the most vital importance. Without it he works in the dark. His engine may be well and properly proportioned, yet hidden defects may exist in the steam passages by the falling or washing of cores which reduces or distorts the passages, yet are not easily detected by the eye.

"The writer remembers during a somewhat extended experience many instances of this. In two cases he has found the exhaust passages entirely closed, and yet it was not detected until the engine had steam on it and an attempt was made to have it move. Other cases have come under his notice where the passages have been but partially closed—here the indicator reveals it at once. The writer knew of an engine 16×40 inches made by a popular firm for a party to put in a large building for the purpose of supplying power to tenants. The machine was got up with great care from new patterns, and being in a good location to show, it was intended as a model engine by the makers.

"It proved to be, however, a very expensive machine to run. New and improved boilers were put in, but without materially reducing the amount of fuel consumed. The engine was overhauled repeatedly by the makers, who did everything within their knowledge to improve it, but without effect. The power generated cost too much. The landlord lost money and failed; the same result followed his successors, and finally the engine was thrown out and its place supplied by another with good results to the owner of the property.

"The old engine was offered for sale, and sold to go in an armoury in an adjoining State. It was overhauled and put in good condition so far as could be seen, and put at work, but with

the same result—a large consumption of fuel for the power available. After all other expedients had failed, the indicator was applied, when it was found that with an initial pressure of 60 pounds there was a back pressure of 15 pounds! Here, then, was revealed the cause of the trouble. On examination, the exhaust passage was found obstructed; the cores had not met properly, and the exhaust steam had to pass through an aperture of about a square inch in area. On cutting through the side pipe and removing the slight obstruction the engine performed a duty due to the fuel consumed.

“On another point of great importance to the well-working of the steam engine the indicator is invaluable—the setting of valves. Most engineers think they can set their valves by the eye, but an experience, somewhat extended, with the indicator has shown the writer that as a rule this is a fallacy; valves have to be set by the eye when the engine is not under steam, hence the expansion, the springing of the various parts, which cannot with certainty be ascertained, consequently it is seldom that they are right. The indicator, then, is the only way known by which valves can be perfectly adjusted.

“Until the year 1862, the instrument in use previous could not be used on engines of quick motions with any satisfactory result. At the great exhibition of that year, in London, an indicator was exhibited, invented by Mr. Charles B. Richards, of Hartford, Conn., by which diagrams, correct and entirely reliable, are taken under any attainable speed; hence locomotives and any other quick-running engines are indicated with equal accuracy as the large slow-moving marine engine.

“Another important fact is proved by the indicator—the exact amount of power exerted by the engine; this, compared with the fuel consumed, enables the engineer to compute with exactness the cost per horse-power, also the quantity of power used for certain work or by different tenants. About this there is no guess-work; it is absolutely weighed and measured.

“The custom of renting power by a belt of given width and velocity is fallacious. It is easy to tell what power a belt should transmit, yet it is utterly impossible to tell how much it will transmit; so many contingencies arise, some of which follow the quality and condition of the belt, the condition of the pulleys,

the amount of contact with pulleys, the position—whether vertical, horizontal, or diagonal; which side is the draft on; whether the grain or flesh side is in contact with the pulley, the tension, the condition of the atmosphere, etc. The only reliable mode is to measure the work by the indicator. By it we can ascertain the comparative value of different kinds of fuel, also of lubricants, the ability and faithfulness of the engineer and fireman; in fine, all elements which assist in making and using steam efficaciously and economically.”—*Scientific American*.

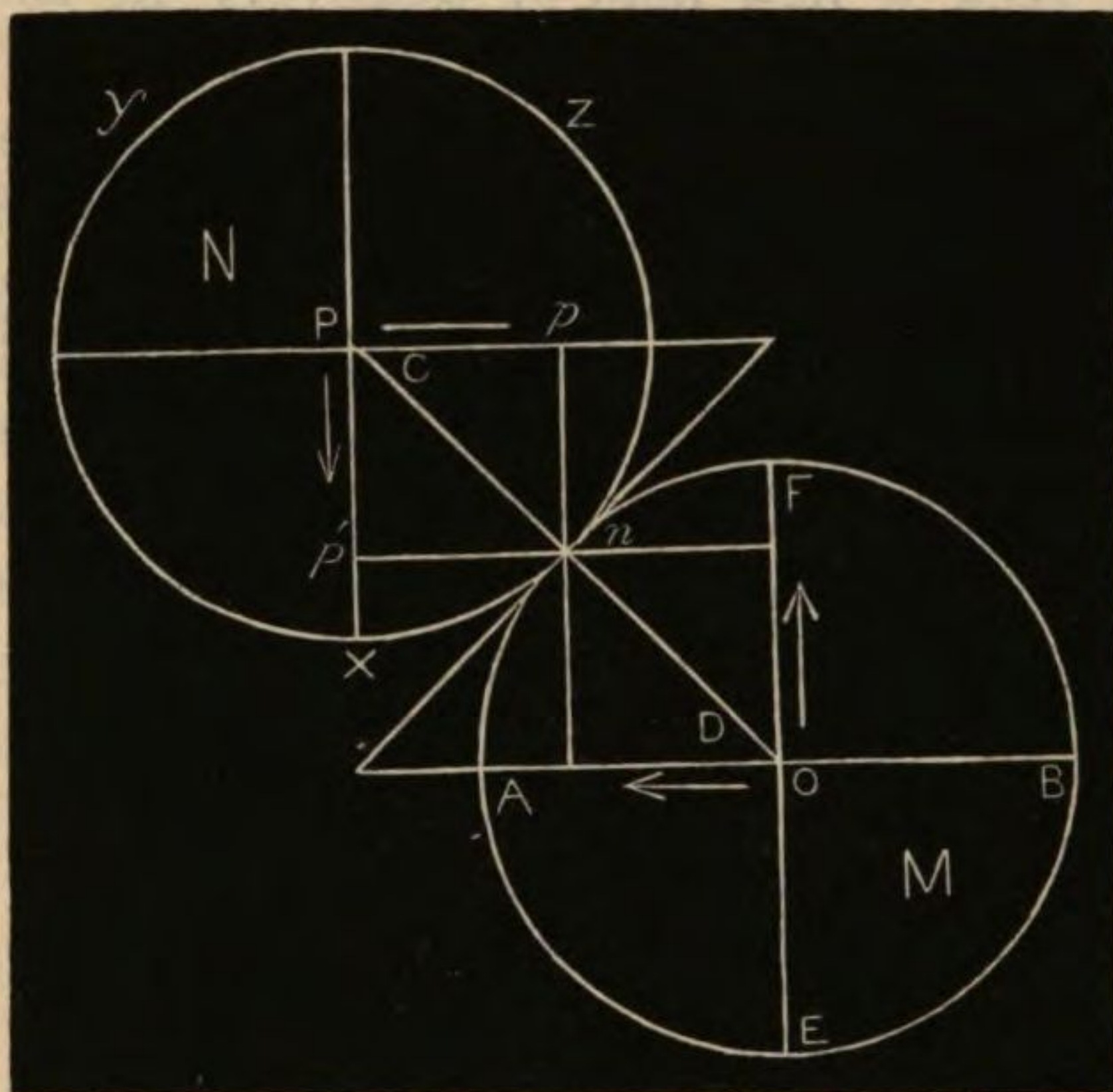
47. *On the Friction of the Slide Valve and its Appendages.*—A very elaborate paper on this subject was read before the Society of Engineers by Mr. Thomas Adams, of which we have room for the following portions:—“The slide valve as at present almost universally used on the steam engine, was invented by William Murdock, of the Soho Works, at Smethwick, near Birmingham, somewhere about the year 1784. It was first set to work without either lap or lead, but subsequently he added a sixteenth of an inch of lap, and subsequently again a sixteenth of lead, and in that state he left it, and, although engineers since that period have extended the proportions of lap and lead, yet the primary elements—lap, lead, and travel—remain as they left the hands of Watt’s companion. Notwithstanding the enormous amount of power required to work this valve and its appendages, engineers prefer it to any other known form because of the facilities which it affords for a ready admission of steam. Any required amount of expansion and a liberal lead for exhaust, and requiring no other gear to work it than a rod direct from the valve to the eccentric, thus avoiding complication of parts and ensuring simplicity and certainty of action. Probably on no portion of the steam engine has there been more time spent in study, more money spent on patents and trials, or a greater number of engineers made an attempt which has proved unsuccessful. In fact, there is no engineer of any repute, past or present, who has not devoted some of his time in the endeavour to remove the weight from the back of the valve; but so fickle and deceitful a piece of mechanism has it proved itself to be that it has hitherto baffled the united skill of all, until at length it was considered impossible to produce a frictionless slide valve. Such a long list of unsuccessful attempts is enough

to discourage the most determined perseverer, were he not stimulated by that hope of reward which must attend the successful accomplishment of the principal and only remaining improvement of worth connected with the steam engine. To the accomplishment of this task the author set himself nearly four years ago, and he has laboured without intermission in designing and making experiments during the whole of that period. For nearly three years it completely baffled him, setting all attempts at defiance, until at length he was compelled to leave the beaten path of engineers and seek a new field of discovery in the relation of surface to pressure. The steam is master, and will go between the surfaces until a force is applied greater than the area of the surface in contact multiplied by the pressure. This is the fundamental principle, the discovery of which immediately produced a frictionless slide valve, bearing on the face of it the impress of simplicity. All engineers are of one accord in ascribing the loss of a large amount of power in working the slide valve, but there is a large diversity of opinion as to what that amount of power is, solely because there is no correct data from which they may calculate it as they do other sources of power. A paper on the slide valve, then, would be incomplete did it not bring within the range of its consideration two questions. First, what is the magnitude of the evil of which it complains; and, second, what is the remedy for that evil; and to set about such a task the first thing to be done is to ascertain the coefficient of friction under the circumstances attending its practical application, and by that ascertained function to calculate the amount of work performed by the force expressed by the coefficient of friction passing through space, and by the time in passing through that space, and upon the principle of work done, find the proportion which that power bears to the total mean power of the piston.

“The question is often asked, ‘what is friction?’ and the answer given is invariably, ‘a certain amount of force proportional to the weight, or imposed at right angles to the line of motion,’ but which proportional force varies not only with a variation in the constitution of the substance, but also with a variation in the weight imposed; and recent experiments show that it varies also with the temperature of the substance employed, increasing in proportion to an increase of temperature. As this

proportional force must of necessity depend in a great measure on the geometrical form of the molecules of the substance, an investigation into the constitution of the molecular construction of metals from their ultimate atoms is required. The coefficient of static friction cannot be reckoned upon the principle of work done, because it is only a force, and being a force, there must be a limiting angle to it, and that angle will be 45 deg., no matter what the form of molecule; for let us see fig. 19. Let A B be

Fig. 19.

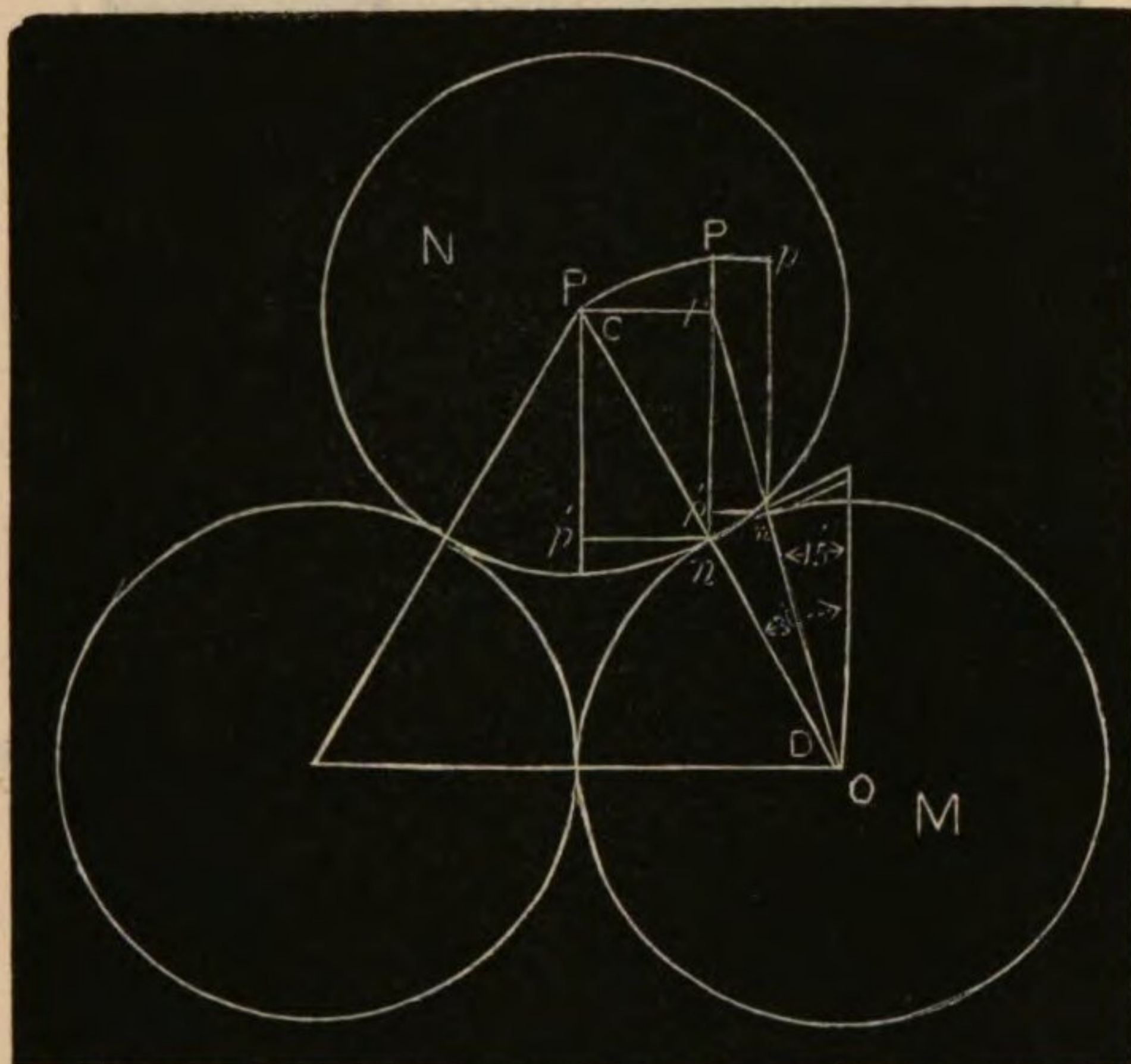


a datum line, and E F a line at right angles. On O, as a centre, describe the circle A F B E; bisect the arc A F in the point n , then the angle A D n will be an angle of 45 deg. Join O n and produce it to P. On P, with the radius O A, describe the circle X Y Z. The centre of molecule N will be at angle of 45 deg. with the line A B. Set off P p equal to sine C, and P p' equal to cosine C. Let sine and cosine C be the two sides of the parallelogram of pressures, join $p n p' n$, and draw the diagonal P n , and produce it to O; it passes through the centre of molecule M; it is therefore stable. Similarly on O, as a centre, construct, and tangent C is equal and opposite to tangent D. The parallelogram of forces to resist those of molecule N and the diagonal O n produced, also passes through the centre P of N. The forces and resistances are equal and opposite, and balance

each other. They must, therefore, be in a state of rest, because there is no force on either side capable of producing motion, and hence 45 deg. is the limiting angle of friction, and from this the coefficient of friction must be calculated, because the sine of this angle, and not radius, is unity.

"Fig. 20 is the spherical form of molecule, and the greatest angle of contact is 30 deg. To find the mean static coefficient

Fig. 20.

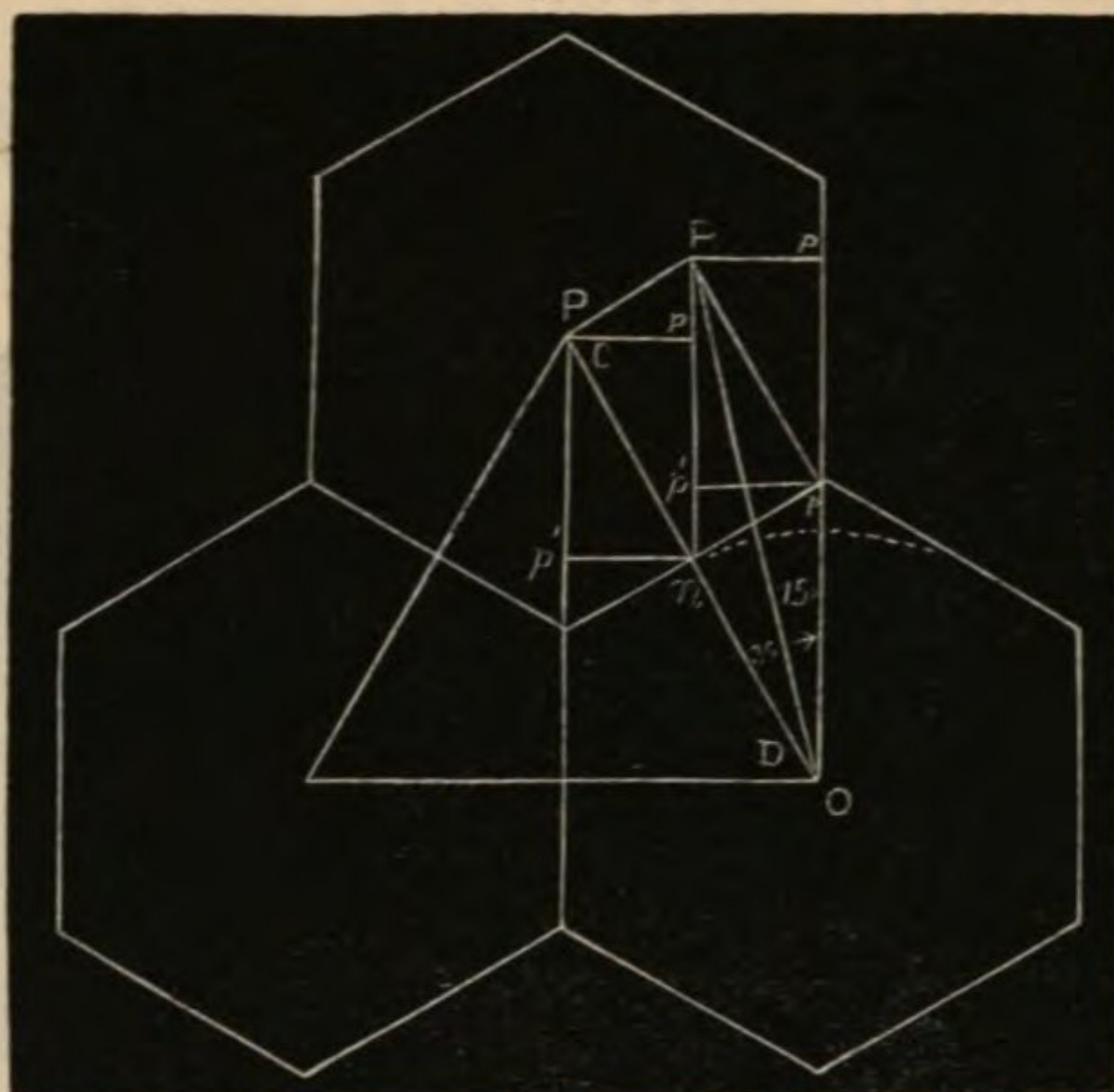


of friction of N in passing over M, is the sine of the angle of every 5 deg. They are added, and their sum, divided by their number, gives a mean of .2973 of the limiting angle of friction. The parallelogram of forces is here constructed as in fig. 19.

"Fig 21 is the hexagonal form of molecule, and has a higher coefficient of friction. For while in fig. 20 the side of the parallelogram of forces represented by the side of the angle decreases from 30 deg. to 5 deg., while the same sine of the hexagonal form remains constant down to 10 deg., the calculation gives a mean of $\cdot 3768$ of the limiting angle of friction, and
$$\frac{\cdot 3768 - \cdot 2973 \times 100}{\cdot 3768} = 21$$
 per cent. in favour of the hexagonal form. And so steel and homogeneous metals, which partake more of the hexagonal form

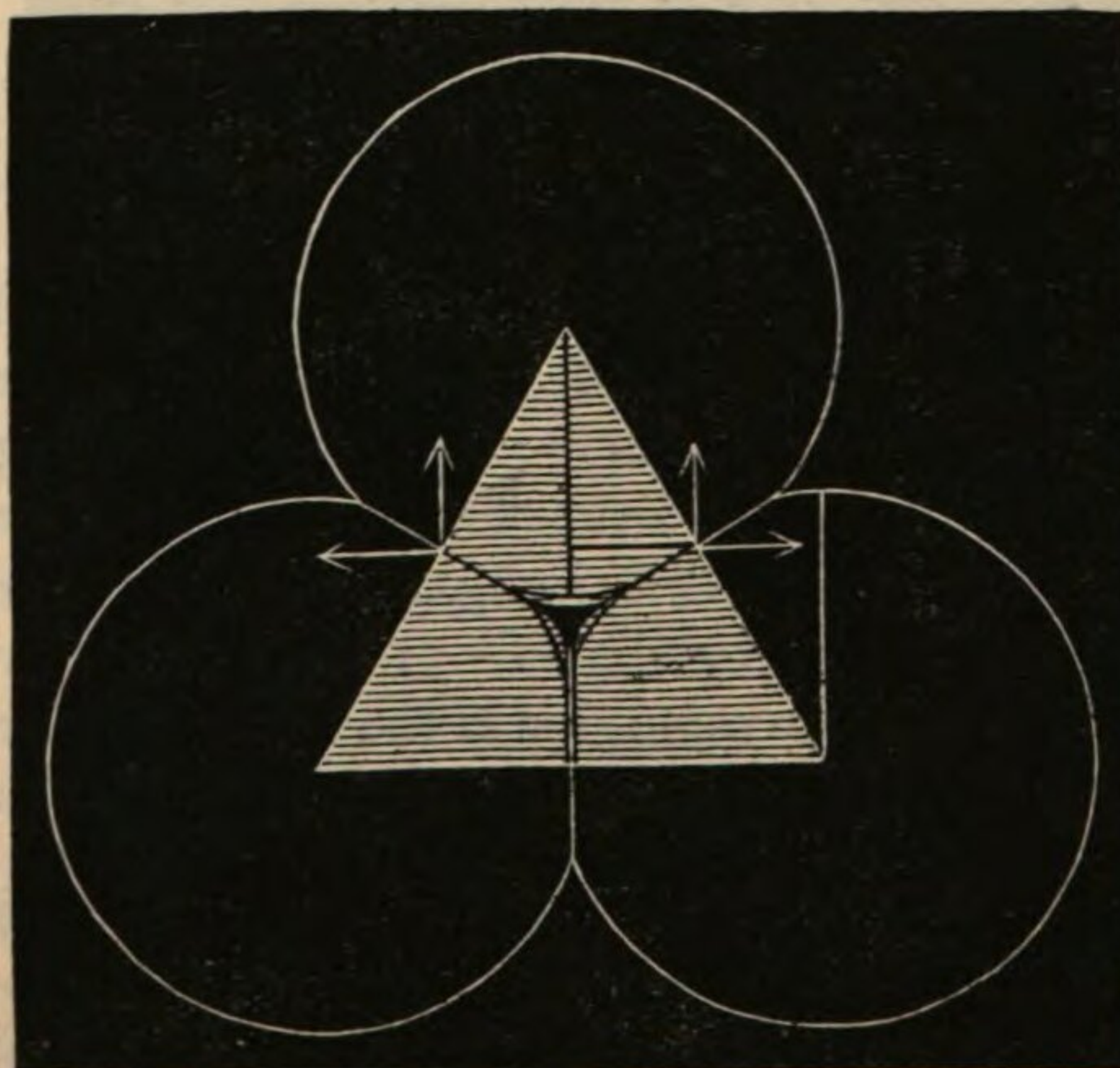
than iron, are better suited for rails and wheel tyres, either engines or carriages, and are, in point of tear and wear, practically indestructible.

Fig. 21.



“ Fig. 22 shows three molecules, neither the hexagon nor the sphere, but partly both, which is no doubt the state in which

Fig. 22.



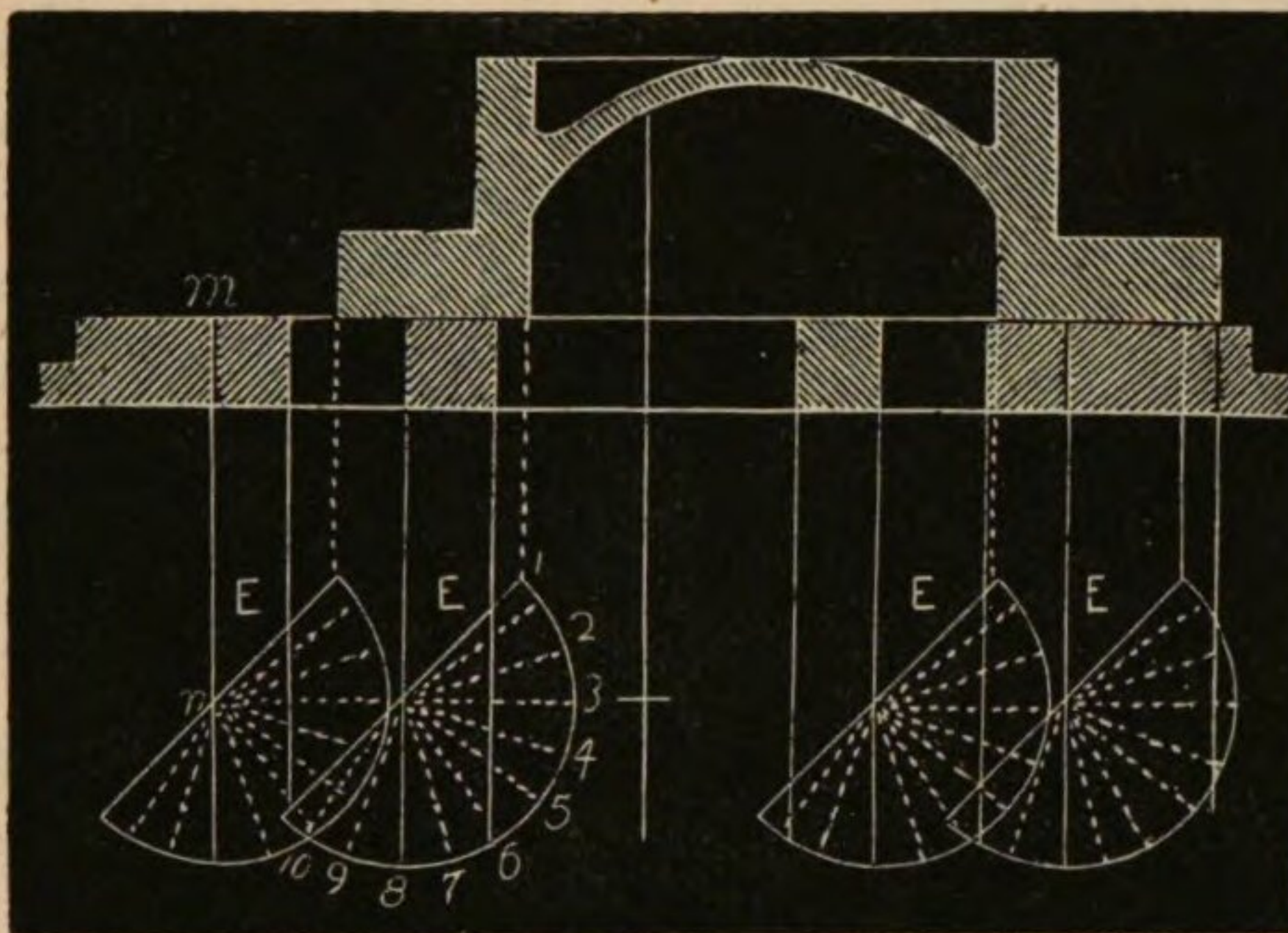
metals exist under the atmospheric temperatures. The arrows show the direction of the motion of the molecules as their centres recede from each other, and the opposite when they approach each other, and any one will at once see the friction to be overcome by their rubbing along the flat side. This is molecular friction, and this force has to be overcome, whether the molecule be subjected to an increase of temperature on an increase in the polar forces, or by the force of tension, or by compression. And the sum of these forces is equal to the entire energy of the universe.

“With this preliminary investigation into the nature of friction, we will proceed with the practice of the evil of which the paper complains, viz.:—‘What is the amount of power absolved in working the slide valves and appendages of the steam engine?’ For this purpose the author had a cylinder face valve box and valves made for the purpose of experimenting upon a variety of forms of valves, a chain being attached to the valve spindle and passing over a pulley on which was hung a scale into which weights were placed, until motion of the valve was produced, the valve being at all times started from its middle position. The bearing surface of the valve is one-half of the back, or 50 square inches, which gave, with 60 lb. of steam, a pressure of 120 lb. per square inch, the area of the valve being 100 square inches; the valve was then recessed in the face, leaving only a strip all round it of three-eighths of an inch, equal to one-seventh the area of the back, which, with 60 lb. of steam, was equal to 420 lb. per square inch. The results are the mean of ten trials each, and care was taken that no lubricant of any kind was present—neither matter nor moisture—in the steam, the trials being made only when good blue steam showed itself at the cocks, and the coefficient of friction was taken at the point where motion began. With steam of 10 lb. pressure, with a temperature of 240 deg. and a pressure per square inch of 20 lb., cast iron on cast iron gave a coefficient of .206; at the same temperature, and 70 lb. per square inch of bearing surface, it gave a coefficient of friction of .235. With 60 lb. of steam and a temperature of 381 deg., and a pressure of 120 lb. per square inch, it gave a coefficient of friction of .269; at the same temperature, and with a pressure of 420 lb. per square inch of surface, it gave a coefficient of friction of .362. With brass upon cast iron the corresponding tempera-

tures and pressures gave corresponding coefficients of friction of .184, .210, .236, and .354, showing that as the temperatures rise the coefficients approach nearer to each other. With the valve as in the first series, and with a V-piece cut out to admit steam into both admission ports, and a hole in back of valve to let the steam through into exhaust cavity, and all three cocks shut, the valve moved as easily with steam on as off, showing that without the exhaust cavity and ports the valve will be practically frictionless. This experiment was only lately tried to prove the principle of the frictionless slide valve. It is quite natural that the coefficient of friction should increase with an increase of temperature, because an increase of heat is synonymous with a decrease in cohesive force of the molecule, and it, at the same time, means that the asperities of the metals in contact are more easily knocked off, and when knocked off the molecule is rolled along the surface until it is crushed by excessive weight. A greater or less number of these molecules are set at liberty every stroke, and this causes the coefficient of friction to be never twice alike, and so practical friction is a compound of true friction and crushing; there is abundance of evidence of this in the application of superheated steam by the excessive wear of the surfaces in contact, the excess of heat lessening the cohesive force of the molecule, the increase in the coefficient of friction, and the steam so dry as to banish not only the presence but the very idea of a lubricant, until, if the heating of the steam, whether under saturation, pressure, or by the superheating process, be carried high enough, we should have the cohesive power of the molecules of metal utterly destroyed, and it would then exist in a liquid state. Extremes are always good for illustration. But there is a temperature at which the coefficient of friction and the cohesive force of the molecule will balance each other and become equal; and between this temperature and that of fluidity the coefficient of friction would decrease, but the destruction of the molecules would increase, which would record itself by an increase in tear and wear. This doubtless takes place in many cases of superheating. The nature of cast iron also is such that its composition can be varied to give a coefficient of friction on dry hot surfaces ranging from .18 to .21, according to the closeness, texture, and hardness of the composition.

"In the annexed engraving, fig. 23 represents the valve of No. 47 engine, North London Railway, being a section over the ports at commencement of stroke. The dimensions of the engine are—diameter of cylinder, 17 in.; stroke, 24 in.; lap of valve,

Fig. 23.

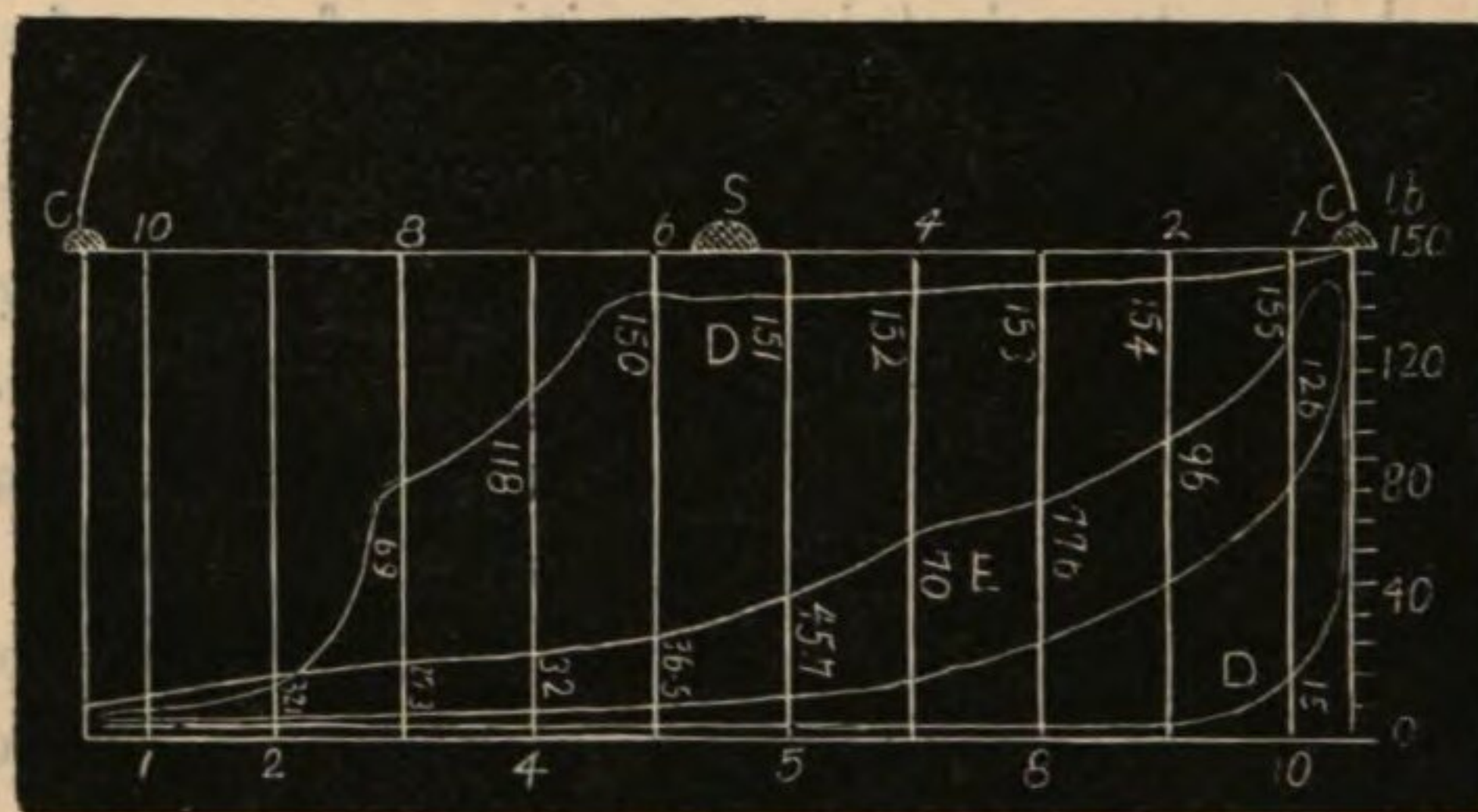


$\frac{7}{8}$ in.; lead, $\frac{1}{2}$ in.; travel, 4 in.; position of gear, fourth notch from mid-gear, there being five notches for fore, and five for back gear from the central one; diameter of driving wheel, 5 ft. 6 in.; number of revolutions, 140; pressure in boilers, 160 lb. per square inch. The outer and inner edges of the valve, by their crossing the outer and inner edges of the ports and bars on the cylinder face, determine the distribution of the steam. If, then, we draw lines $m n$, and from each of those edges, and at right angles to the plane of the valve's motion, and at any convenient distance below and on the lines, let fall from the outer and inner edges of the valve while in its middle position, describe semi-circles E, &c., equal to the travel of valve; divide these semi-circles into ten equal parts, each corresponding to the ten equal divisions on the indicator diagram D. Let the pressure on the back of the valve be represented as positive pressure, and that on the face and in the exhaust cavity as negative pressure. Measure the horizontal distances from each division to the edge of port or bar, and find what section of surface of valve is exposed to negative pressure; that section multiplied by the length of the port, and by the corresponding pressure on diagram, will give the

total negative pressure, which, taken for the ten divisions and their sums added together, and divided by 10 to give their mean, and that sum subtracted from the total positive pressure, will leave the positive force available for friction, which, multiplied by the coefficient of friction, and by the feet passed through by the valve per minute, and divided by 33,000, will give the horse power required to move the valve. The positive force of the valve multiplied by the coefficient of friction will be equal to the direct pull or force on the eccentric, and this force, multiplied by the coefficient of friction due to a cold lubricated surface, and by the space passed through by the periphery of the eccentric in feet per minute, and divided by 33,000, will give the horse power required to work the eccentric. Let S be the centre of the axle, and SC the length of the crank, then will CO be the path of the crank pin, and CC the stroke of piston.

"Let D , Fig. 24, be a diagram ; divide it into ten equal parts in the usual way, and draw ordinates across the diagram, marking

Fig. 24.



on those ordinates the respective pressures and back pressures, and in the ordinary way find the horse power of the cylinder, care being taken that the same mode of finding the horse power of the friction of valves and eccentrics be used, and that that mode will be the acknowledged and established rule amongst engineers.

"In constructing a table the first column should show the number corresponding to the number on the diagram ; the second column should be the sectional breadth of the valve in inches exposed to negative pressure ; the third column the length of the valve exposed to that pressure ; and the fourth column the pres-

sure in pounds per square inch taken from the diagram ; the fifth column should be the second, third, and fourth multiplied together, giving the total force in pounds tending to press the valve from its face. The same operation being performed for the ten divisions and the totals added, and that sum divided by 10, gives the mean negative pressure. This is for the outside or admission edge of valve and left-hand side, the same thing is done for the other three edges of the valve ; their sums are added and their mean taken, which gives a total mean pressure of 1,891.14 lb. as negative pressure, and this pressure subtracted from the total pressure on back of valve leaves the force available for friction thus :— $18\frac{5}{8} \times 9\frac{7}{8} \div 160 = 29.440 - 1,891.14 = 27,548.86$ available force ; a column giving the bearing surface in square inches or the number of inches in the valve bearing on the cylinder face for its respective position, which being added together, gives a mean of 64.8. Then $\frac{27,548.86}{64.8} = 426$ lb. per square inch ; and from this number the coefficient of friction of brass on cast iron is .354. The next column is the pressure on the diagram, and the last is the back pressure, which, on being added, the less is subtracted from the greater, and divided by 10, to give the mean pressure in the cylinder. Then the following is the calculation :— $18\frac{5}{8} \times 9\frac{7}{8} \times 160 = 29,440 - 1.899 =$

$$\frac{(27,548.86 \times .354 \times \frac{9}{12} \times 140)}{33,000} = 27.476\text{-H.P.} \times 2 \text{ for two valves}$$

 $= 54.952\text{-H.P.}$ equal to friction of both valves.

“The eccentrics are 16 in. diameter and $2\frac{3}{4}$ in. broad. The bearing of the eccentric strap is equal to $16 \times 2\frac{3}{4} = 44$ square inches of bearing surface ; in this case it is equal to $\frac{27,548.86 \times .354}{44}$
 $= 221$ lb. per square inch.

“As no experiments were made to determine the coefficient of friction of the eccentric, it is taken at a low number, .15 being a cold lubricated surface. Then, $27,548.86 \times .354 = 9,752.296 \times .15 \times 5.5 \times 140$

$$\frac{9,752.296 \times .15 \times 5.5 \times 140}{33,000} = 37.163\text{-H.P.} \times 2 = 74.326\text{-H.P.}$$

 equal to friction of the eccentrics ; and $74.326 + 54.925 = 129.251\text{-H.P.}$ equal to the friction of valves and eccentrics ; and

$$\frac{227 \times 109.1 \times 560}{33,000} = 420.266\text{-H.P.}$$
 of one cylinder, which $\times 2 = 840.532\text{-H.P.}$ of both cylinders ; and $840.532 - 129.251 =$

$\frac{711.281 \times 100}{840.532} = 84.6$ per cent., and $100 - 84.6 = 15.4$ per cent. of the power of the engine required to work the valves and eccentrics. Thus we see that eccentrics of this diameter exert a greater brake force on the engine than does the friction of the valves by 20-horse power. But the eccentrics are the unavoidable appendages of the valve, and the loss by the one is the inevitable and certain loss by the other; the one is the hand-maid to the other, and they are bound together by natural and insoluble ties, by which they cannot be parted. This is an example of an engine working in one notch from full gear.

"The next example will be an express engine on the Great Northern Railway, working in the first notch from mid gear, and running at a speed of fifty-five miles per hour. Diameter of cylinder, 17 in.; stroke, 24 in.; lap of valve, $1\frac{1}{4}$ in.; lead, $\frac{1}{2}$ in.; travel, $3\frac{5}{8}$ in.; diameter of driving wheel, 7 ft.; number of revolutions, 220; pressure in boiler, 160 lb. per square inch. For the purpose of comparing the variation which the percentage of the friction of the valve bears to the percentage of the cylinders' power, which ranges between 10 per cent. and 55 per cent., according to the variation in the position of gear—for while the cylinder decreases in power, the friction of valve and appendages increases until, by a decrease on the one hand and an increase on the other, the valves and eccentrics absorb upwards of half the power of the cylinders—let E (see above diagram) be the diagram, taken in the first notch from mid gear.

"The following are the dimensions and numbers for the Great Northern Railway, exactly as described and explained for the North London Railway engine. The pressure per square inch of valve being 431 lb., the same coefficient of friction is used as for the other, and the following is the calculation:—Dimensions of valve, 20.25×11.5 in., then $20.25 \times 11.5 \times 160 = 37,259.2$
 $-4.503 = \frac{32,756.2 \times .354 \times 7\frac{1}{2} \times 220}{33,000} = 46.551\text{-H.P.} \times 2 =$
 93.102-H.P. equal friction of valves, $32,756 \times .354 =$
 $\frac{11,567.64 \times .15 \times 5.5 \times 220}{33,000}$
 $= 63.652\text{-H.P.} \times 2 = 127.304\text{-H.P.}$ friction of eccentrics, and
 $93.102 + 127.304 = 220.406\text{-H.P.}$ friction of valves and eccentrics, and $\frac{227 \times 32 \times 880}{33,000} = 193.44\text{-H.P.} \times 2 = 386.88\text{-H.P.}$

of both cylinders, and $386.88 - 220.406 = \frac{166.474 \times 100}{386.88}$
 $= 43$ per cent., for cylinders ; $100 - 43 = 57$ per cent., equal to friction of valves and eccentrics.

“Thus it will be seen that the friction of the valves and eccentrics when working in this position is equal to more than half the power of the engine, and the mode of calculation is as correct for the one case as for the other. What is correct for the finding of the power of the cylinder is also correct for the finding of the friction of the valves and eccentrics, since the same rule is applied to both. And the variation of the percentage of power required to work the valves and appendages ranges according to the position of gear by the link motion from about 12 per cent. in full gear to 56 per cent. in the first notch from mid-gear, when running at a high speed, producing considerable back pressure.

“We will now examine into the proportions of the piston rod and valve spindles, and see how these calculations agree with actual practice, and take as an example the North London Railway engine—diameter of piston rod $2\frac{3}{4}$ in. ; sectional area, six square inches ; greatest force on piston rod, 36,320 lb. ; then $\frac{36.320}{6} = 6,053$ lb. per square inch of section. Diameter of valve spindle, $1\frac{5}{8}$ in. ; sectional area in square inches, 2.07 ; mean force on valve spindle, 9,552 ; then we have $\frac{9.522}{2.07} = 4.614$ lb. per square inch of section, which shows the calculation to favour the relative strength of the valve spindle. Yet we seldom hear of a piston rod breaking ; on the other hand, we are continually hearing of valve spindles breaking. About two months ago two of those very valve spindles which have just been calculated broke and doubled up as if they were no stronger than a willow. And only last week another of those very spindles broke in about the middle of its length.

“When the author took the dimensions of the Great Northern Railway express engine it was in the shed getting a new buckle, it having been broken. And this sectional area of buckle only receives one-half of the force, because, the valve spindle being in the centre of the buckle, the force is equally divided between the two sides of the buckle.

"Now the section at A is 2 in. deep by $\frac{3}{4}$ in. thick, equal to $1\frac{1}{2}$ square inches, and the mean force on the valve spindle is $\frac{11.567}{3} = 3.841$ lb. per square inch, while we know that the breaking weight of iron (for these things are made of the best material) of that section is 56,000 lb. per square inch, upwards of fourteen times the calculated force. What, then, broke it? The greatest pressure which comes upon the valve is when the bearing surface is 66 square inches, equal to 496 lb. per square inch, and this with the metals at a temperature of 370 deg. These two forces—temperature and pressure—combined together for the purpose of uniting the molecules of the valve and cylinder faces together, and nothing short of it will break the spindles, because we see that the total force on the valve, multiplied by the coefficient of friction, does not amount to one-fourteenth of the breaking weight of the spindles. Mr. Matthews, of the firm of John Penn and Son, says that this is the true measure of friction when the spindle comes in two. Other cases than this have been calculated by the author, who is of opinion that 500 lb. pressure per square inch of bearing surface, with the corresponding temperature of saturation of 160 lb. of steam, is beyond the limits of safety, and is entering on the confines of molecular union of the metals.

"And next of the back pressure and compression. The sum of the pressures of the Great Northern express engine is 549, and of the back pressure and compression 228.4.

Now $549 - 228.4 = \frac{320 \times 100}{548} = 58.4$ per cent., $100 - 58.4 = 41.6$ per cent., which is the proportion of back pressure to total pressure. And $\frac{227 \times 22.8 \times 880}{33,000} = 138\text{-H. P.} \times 2 = 276\text{-H. P.} = \text{back pressure, which added to friction of valves and eccentrics} = 496\text{-H. P.}$

"Now the total force of the steam on the propelling side of the piston is $— \frac{227 \times 54.9 \times 880}{33,000} = 361\text{-H. P.} \times 2 = 722\text{-H. P.}$ for both cylinders. And $772 - 496 = \frac{226 \times 100}{772} = 31.3$ per cent. of the power of the steam used for commercial purposes.

"We will now take an example of the marine engine, and for

that purpose we will select the engines of the 'Warrior' (ironclad):—Effective diameter of cylinder, $104\frac{1}{4}$ in.; stroke, 4 ft.; revolutions, 56 per minute; lap of valve, $5\frac{3}{4}$ in.; lead in full gear, 1 in.; travel, 20 in.; pressure in boiler, 27 lb. per square inch.

"Engines by other makers could have been selected from which a much larger percentage of friction would have been got, but I have selected the 'Warrior,' because her engines are acknowledged to be of the very best description made, both as regards the mechanical element of the design and the workmanship; and if the ordinary valve packing can be made and kept steam-tight, it will be done by the builders of these engines, and if we cannot find it there we may save ourselves the trouble of further search. The valve being cast iron on cast iron, and the pressure per square inch of surface being 121 lb., the coefficient nearest to this is .260. In judging of the friction by reversing an engine with steam on, we do not overcome more than half the power represented by friction, because we can only move the valves, and, practically, not the eccentrics, because the small arc through which the eccentric straps pass, reduced by the long leverage of the rods, is not worth accounting for, and as the eccentrics represent more than half the frictional power, we are only overcoming half that power in reversing.

"The engraving F, fig. 25, represents a diagram taken from the engines of the 'Warrior.' The calculation for the 'Warrior' engines is made the same as the others, and the following is the result:— $79 \times 50 \times 42 = 165,900 - 39,512 =$

$$\frac{(126.388 \times .260 \times 3.333 \times 56)}{33,000} = 185.7\text{-H. P.} \times 2 = 371.4\text{-H. P.}$$

$$\text{friction of valves; } 126.388 \times .260 = \frac{32.861 \times .15 \times 17.54 \times 56}{33,000}$$

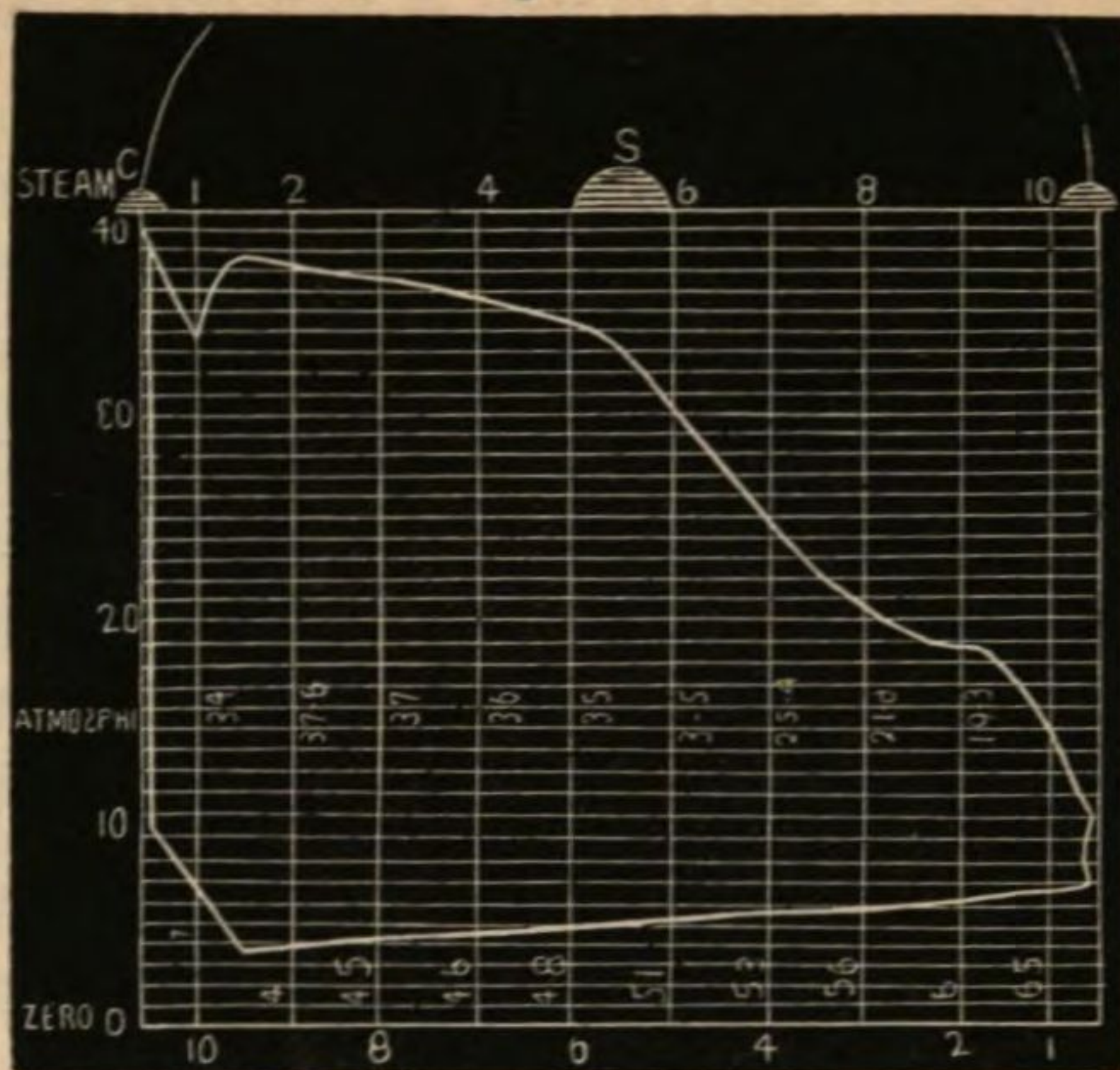
$= 146.815\text{-H. P.} \times 2 = 293.630\text{-H. P.}$ equal to friction of eccentrics; and $371.4 + 293.630 = 665.030\text{-H. P.}$ to work the valves and eccentrics of the 'Warrior's' engines. 104.25^2

$$\times 7,854 = \frac{8,375.75 \times 23.9 \times 448}{33,000} = 2,704\text{-H. P.} \times 2 =$$

$$5,410\text{-H. P. of both cylinders. } 5,410 - 665.030 = \frac{4,744.970}{5,410}$$

$= 87.5$ per cent., and $100 - 87.5 = 12.5$ per cent. of the power of the engines to work the valves and appendages of the 'Warrior.' It will be seen that the valves require a greater

Fig. 25.



amount of power to work them in this case than the eccentrics, the reason being that in the former case the proportion of travel of valve to diameter of eccentric is about 1 to 4; in this case it is about 1 to $2\frac{1}{4}$, which quite accounts for the difference. It will be seen that no deduction is made for the packing in the back of the valve. The author wishes it to be distinctly understood, and without any palliating circumstances, that there is no elastic vegetable packing in the back of the slide valve, which is steamtight in practice, no matter by what maker."

48. *Equilibrium Slide Valve*.—"We have several times alluded," says the Editor of Engineering, "in this journal to the equilibrium slide-valve patented by Messrs. Adams and Parsons, a valve which is now being extensively applied to locomotive and other engines; and we now give an engraving of it as fitted by Mr. James Johnson, the locomotive superintendent of the North Staffordshire Railway, to ten of his inside cylinder goods engines."

"From the engraving (not given here), it will be seen that the slide-valve has in this case a pair of short cylinders formed on the back of it, and that each of these cylinders is furnished with a cast-iron packing-ring, these rings fitting the cylinders closely, and bearing against a plate fixed down the centre of the valve-chest."

The spaces enclosed by the rings are, of course, in free communication with the exhaust. Each ring is kept from shifting round by means of a small steady pin as shown on the left hand side of the section, and a pair of slight springs, placed between each of them and the valve, keep them constantly in contact with the central plate. Each of the packing rings is bell-mouthed at the end which bears against the central plate, the inside diameter of the bell-mouth being made the same as the outside diameter of the other part of the ring, and by this arrangement the areas at each end of the ring acted upon by the exhaust steam are equal to each other.

“The engines on the North Staffordshire Railway to which the particular valves, which we are now describing, are fitted, have cylinders 17 in. in diameter with 2 ft. stroke, and the ports, &c., are of the following dimensions:—steam ports 17 in. by $1\frac{3}{8}$ in.; exhaust ports 17 in. by $3\frac{1}{2}$ in.; width of bars 1 in. As the valves have neither inside lap nor clearance, the area of the exhaust openings in each of them is equal to $17 \times 5\frac{1}{2} = 93.5$ square inches, whilst the areas inclosed by the two packing rings with which each valve is fitted are, together, slightly greater, the inside diameter of each ring at the bell mouth being $7\frac{3}{4}$ in., making the area enclosed by each 24.347 square inches. The thickness of each ring is $\frac{3}{8}$ in., and the cylinders to which they are fitted are situated with their centres at equal distances from the centre of the valve.

“The plate which is fixed in the centre of the steam-chest, and which forms the face against which the packing-rings work, has formed on it at one end feet, which fit upon conical studs screwed into the back end of the valve-chest. At the other or front end a couple of screwed studs are fixed across the valve-chest, one near the top and the other near the bottom; these studs pass through the central plate, and are each furnished with a nut on each side of it, so that the plate can be readily set in a central position, and parallel with the valve faces. In many instances Mr. Adams fits his slide-valves with one large packing-ring only; the arrangement with two smaller packing-rings, however, is one which is convenient in many cases, and it allows the buckle or frame on the valve-spindle to be dispensed with, and the form of spindle shown in the engraving substituted.

“In order to maintain a film of steam between the working surfaces, those parts of each valve forming the lap have each a recess $\frac{5}{8}$ in. wide and $\frac{3}{8}$ in. deep formed in them, as shown in the section. These recesses pass over the ends of the valve face at each stroke of the valve, and are consequently kept full of steam, whilst from their position the steam is never discharged into the exhaust.

“A really good equilibrated slide-valve, which can be readily applied to locomotive engines, is no doubt a great desideratum, and the one which we have described has been found in practice to answer exceedingly well, the movement of the valves being almost frictionless. Besides the engines on the North Staffordshire line, others have also been fitted with it on the North London, the Great Northern, the Midland, the Manchester, Sheffield, and Lincolnshire, the Great North of Scotland, the Caledonian, and the Great Eastern Railways, an engine on the latter line to which it has been applied having now been running about fifteen months satisfactorily. It is also being applied to marine engines, both by the admiralty and by some of the marine engine builders, and it is coming into use on the Continent.”

49. *Steam Power Doubled without Additional Fuel.—Is this Possible?*—Mr. Thomas Ewbank has thus addressed the Editor of the “Civil Engineer and Architect’s Journal” on the above suggestive subject:—“As progress in the arts requires us to advance from empirical and partial to rational and extended applications of science, occasional recurrence to first principles, if not always requisite, is not often indispensable. For lack of appealing to them, errors, and oversights equal to errors, are apt to become established, till their real character is not suspected, and hardly believed when pointed out. So it has ever been and will be. Referring to beet and cane sugar, a writer announces that the juice of the cane contains double the quantity of saccharine crystals extracted from it—that quite as much is lost in the primary manufacture as reaches the market. Passing by other examples of thoughtless waste, the same may be said of a product vastly more important to commerce and the world at large than the richest of saccharine plants—STEAM POWER. Of it the high-pressure or non-condensing engine is the popular representative, and strange to say, *the fluid positively contains double the amount*

of power which the best class of such engines draw or ever can draw out of it. Hence, if operatives of the last century are rightly considered dullards for wasting materials, what in the next one may not be said of us who, after evolving with costly apparatus the most valuable of motive agents, discharge it into sinks and sewers, or the air, with half its power in it—casting out as worthless dross that in which there is not an atom of refuse or alloy. Expert and alert as we are in many things, we surely shall not be thought adepts in economising that which gives value to every material.

“But are there not engineers who deny that anything like so much power is lost in waste steam? Yes, I think all with whom I have conversed emphatically dissent; and yet the fact appears as clear to other minds as that they exist, and, furthermore, that the alleged amount, so far from being an exaggeration, is largely *under* the truth. Doubtless the views of practical men should command respect; but crucial tests and natural laws, not human opinions, are required here. Truth in too many things is obscure because not deemed worth the trouble of clearing up, but in a matter of such importance to advancing civilization as this it ought not to be left an hour in uncertainty. Nor need it be.

“The subjoined propositions cover the whole ground, and what follows them will, it is presumed, suffice for their demonstration:—1. In all cases there remains *as much* power in the discharge steam as it imparted to the piston, however great that may have been. 2. In most cases *more* power, and in some cases *double the power*, may be obtained from it.

“As I wish to address others beside professional men, a preliminary observation or two will not be out of place; for, though the subject is becoming an item of college education, few look *into* it, and general ideas reach little beyond the external features and movements of an engine. There is no reason why this should continue, nor will it, since whatever is uncertain about steam vanishes when thoroughly looked into, and every person of ordinary capacity can do that. Its properties are as palpable and plastic as those of other bodies. It is weighed in the same scales, and its quantities ascertained by the same measures as liquids and solids. A pound of it is a pound of water evaporized. The mode of using the measures is somewhat different, but not less

rigid and correct. One holding a cubic foot of water has to be emptied and filled afresh till the number is made out; whereas with steam several feet are generally contained in the space of one, the number being indicated by the pressure—hence pressure and quantity are compliments and explicatives of each other. As volume increases pressure diminishes, and *vice versa*, the quantity remaining the same. The smaller volume may comprise the larger: thus five cubic feet of the pressure of 40 lbs. on the inch contain ten feet of 20 lbs., or twenty feet of 10 lbs., all three equivalents in cost, weight, quantity, and power.

“These remarks are introduced to enforce the imperfectly acknowledged truth that the power of steam is increased only by increasing its *quantity*, just as more heat is obtained by consuming more fuel, more light by turning on more gas, and as the force of a gun is increased by adding more powder to the charge. Hence, to double or treble the power of steam in a boiler, double or treble the quantity must be generated in it, for there is no increasing the natural force of the fluid.

“As a source of mechanical power the atmosphere is little thought of, and still less as the recipient of all forces—Nature’s receiving and reacting reservoir. A perfectly elastic medium, it softens the effects of the most violent, and responds to the smallest. To say nothing of natural forces, of which, as in the case of wind, inconceivably minute fractions only have been used, the steam incessantly rising from human applications of heat to water would, if condensed under pistons, yield a productive power equal to the muscular energy of multiplied millions of men and horses, while we of the present age are responsible for recklessly contributing vast additions to the waste. I do not allude to what ascends from domestic habitations and manufacturing processes, but to the volumes discharged from motive engines by those whose profession it is to apply force, and the best proof of whose skill is to economise it. What inference can hereafter be drawn from our employing the force that expands a volume of water into 1,750 volumes of vapour, and neglecting that which is evolved by the shrinking back of the 1,700 into one? What, but that the fact was either not known or overlooked that the negative force in fluids is equal to the positive.

“Nearly all the world knows that a cylinderful of steam is

discharged from a high-pressure engine at every stroke of the piston, and that from the rapidity of the strokes and the high temperature of the fluid, little is lost in passing through the cylinder. Now, *does* every puff of the escaping vapour contain or not an amount of power equal to that it imparted to the piston; in other words, does its shrinking back into water give out power equal to that which raised it out of water, and as fully as a falling weight gives back that which raised it? The answer has just been anticipated, for the question is nothing less than an appeal to the law which governs every form of force and every mode of application—the fundamental law of action and reaction. According to it the two forces are absolutely and inevitably equal. It is impossible for one to be less than the other. They are simply contractions and expansions, equivalents to each other. To exemplify: A high-pressure engine has a piston of the area of 50 square inches, and is worked with steam, say of 60 lbs. to the inch, hence $50 \times 60 = 3,000$ lbs. of *steam* pressure. Now if the fluid, instead of being discharged, were condensed under another piston, it would produce precisely the same result; thus, steam of 60 lbs. contains four volumes of common steam, and would dilate and fill a cylinder with a piston of 200 inches area, both cylinders of one length; hence its condensation would excite an *atmospheric* pressure of $200 \times 15 = 3,000$ lbs. So much for the first proposition.

“If the second be thought to conflict with the first it only appears so. A cylinderful of common steam has *no* expansive force or direct action on a piston, but is all that is required to produce a vacuum under one; so that while the two forces are theoretically equal, the contracting one is practically the most productive. *More power—15 lbs. on the inch more—is obtained by condensing steam of two atmospheres and upwards* than its direct action can give out, because the expanding force acts against the atmosphere, and therefore loses (expends without return) 15 lbs. on the inch, while the contracting one, coinciding with the pressure, gains that much. Hence engines working with 30 lbs. steam, or a pressure of two atmospheres, give out only the force of one; with 60 lbs. steam the force is that of 45 lbs.; of 90, that of 75 lbs., and so on. The term ‘most cases’ in the proposition might be changed for ‘all cases,’ and the ‘some cases’ scarcely

needs a formal exposition. An engine with a piston of 50 inches area, and using 30 lbs. steam, has, of course, an available force of only 15 lbs. steam; hence $50 \times 15 = 750$ lbs. of steam pressure; but the same steam condensed under a piston of 100 inches area would yield double that amount in atmospheric pressure; it would be $100 \times 15 = 1,500$ lbs.

"Perhaps it will be said this is no new discovery. Granted; but it is a great truth, nevertheless, and one hitherto overlooked or not appreciated. Adopt it, and it will be found surpassingly more effective and profitable than the numerous wire-drawings of subordinate devices.

"What is the expense of thus saving waste steam? As the force of a high-pressure engine is deemed to be worth much more than the fuel it costs, an equal additional amount should be held cheap at the same price. Instead of that, however, it is offered as much cheaper as cold water is cheaper than coal. The expense consists in the application of that which may almost everywhere be had for nothing. To decline the advantage offered is to prefer partial results at a great cost to full results at a smaller one; but when the superior productiveness of the shrinking over the swelling force becomes generally known, it will scarcely be much longer neglected. With a separate condenser, the judgment that consigned Newcomen's engine to desuetude will have to be revised.

"To save steam power is to save that which is more valuable than silver or gold. To be careful of evolving and parsimonious in expending it is a virtue—to waste it, a crime. Its economy has relation to the welfare of nations, and henceforth their rise and decline will be influenced by it. It has a direct bearing on a subject of increasing anxiety with European statesmen,—the prospective exhaustion of British coal-fields. The cost of the world's steam power in coal is enormous, and is rapidly increasing. To lose half the power in steam is to waste half the fuel. To save steam is to save coal; and to double the available power of steam is to save half the coal.

"And yet 50 per cent. seems less than what ought to be saved. In the first part of this paper it is declared that steam contains more than double the power got out of its direct action; and it may now be added that not more than *one-third* of it has been

realized in either condensing or non-condensing engines. This fact, no doubt incredible to many, is incontrovertible. (See *Journal of the Franklin Institute* for July, 1865.)

“Another point shows that, instead of anticipating the future in making the most of our steam, we are lamentably in the rear. It is stated that 90 per cent. of the heat is lost in waste steam. To common observation it would appear never to be less, as the piston acts but as a momentary check to the fluid’s passage from the boiler to the waste pipe. Of course every particle dispersed carries off power; and to save it every particle must be liquified *within* the engine, for the power and the vapour live and expire together.

“The mode proposed to utilize the whole force consists principally in adding an atmospheric cylinder to the steam cylinder, as much larger than the latter as the tension of the steam used is above atmospheric pressure, as in the specification and drawings of Benjamin Laurence’s English patent for increasing the mechanical value of steam as a motive agent, dated March 17, 1865.

THOMAS EWBANK,
Late U. S. Commissioner of Patents.”

SECTION SECOND—LOCOMOTIVE ENGINES.

50. *Locomotive Engines.*—We commence this important section of the present Division, by giving, from “Engineering,” a very suggestive article on the future of Locomotive engineering:—“A revolution must yet take place in the construction of locomotives hardly less complete than that which we have witnessed in ships of war. When engines, a few years ago, were occasionally made to weigh 25 tons, there was a great outcry as to the excessive strains which they put upon the way. But we were never increasing the weights of engines more rapidly than now, and there are already two eight-coupled engines on the Great Northern line, and others on the Vale of Neath, which weigh each 56 tons. The North London and the Metropolitan passenger engines weigh 42 tons, with 30 tons on the four coupled wheels, and it is clearly apparent that heavier and heavier engines will yet be required for all the great main lines. Upon the present plan we cannot greatly increase the power of the boiler. Its dia-

meter is already as large as the room between the wheels will admit. It is of no use to greatly increase the length of the tubes. The heating surface thus gained is of very little value, and extra strength of blast is requisite to pull the gases through under the increased tube friction. Even for a mechanical reason long tubes are objectionable, as they are apt to sag and work loose in the tube plates. A very large fire-box, without increased tube surface, is also of little use. The French engineers have met the question of larger engines in a bold and even ingenious manner, as illustrated in M. Petiet's engines, engraved in our last number, (see 'Engineering' Nov. 2d, 1866). But here there is a good deal to object against. To clear the wheels, the firebox and boiler are placed entirely above them, and thus almost any width of grate and any diameter of barrel may be had. But the result is a mountain of machinery 12 ft. high, and liable to roll heavily and dangerously at moderate speeds. Again we are still increasing the working steam pressure. Steam of 160 lb. is regularly carried on several lines, and new engines for one of the great metropolitan lines are being designed to work at 180 lb., and, possibly, 200 lb. Very large barrels are hardly compatible with great pressures. Then there are objections to the mode in which the French engines are carried; for, whether they have ten or twelve wheels, the axles are parallel, and the engine must strain the line in moderate curves. We are not objecting to their four cylinders and double sets of driving and valve gear, for we doubt whether the great tractive force we have considered can be so well obtained with two cylinders as with four. Great steam tractive force corresponds to great adhesion weight, and unless the weight be excessive, say 8 tons to 10 tons upon a single wheel, this can only be utilised by coupling or by additional cylinders. The objections to coupling eight wheels together are manifest, although it is often done on the Continent and in the States, and occasionally in England. Indeed, one engine has been constructed in the States with twelve coupled wheels, all worked by a pair of 20 in. cylinders. With a single regulator and reversing gear, we believe there need be no objection to four cylinders upon a locomotive, and we hear no complaints upon the score of complication in the case of the four cylinder engines now fitted to twin-screw steamers.

"Mr. Fairlie has grasped the whole subject of heavy locomo-

tives in a sensible and practical manner, and we learn that, in addition to those he is already working, he is designing one of 72 tons weight, which is to be built with the expectation that room will be found for it in the Paris Exhibition. By his plan of double bogies of coupled wheels, each driven by a separate pair of cylinders, he not only distributes the weight of the engine, however great, upon eight or twelve points as required, but he obtains great ease of working around very short curves, the governing wheel base being that only of each bogie, which need measure but from 5 ft. to 10 ft., according to the size and number of the wheels. As the firebox comes entirely between the bogies, it may have any width required, up to 7 ft. or 8 ft., if such a width were necessary; and as the boiler has two barrels, a vast extent of effective tube surface is obtained with a moderate diameter of boiler. In the case of the proposed new engine, with four cylinders 18 in. in diameter, for 24 in. stroke, and having two bogies, each with three pairs of 4 ft. coupled wheels, the firebox is to be 12 ft. long by 4 ft. 6 in. wide outside, with grate-bars sloping down each way from the centre, where it is fired, and the two barrels, each 4 ft. 4 in. in diameter, are to have together 408 tubes 2 in. diameter and 11 feet long. The centre of gravity of the whole engine is low, and the footplate will be on the top of the firebox. In all its broader features the system appears to be that upon which all very heavy engines—and such engines are now more and more in request—should be constructed. The plan involves, however, important points of detail. The steam is to be taken through the bogie centres, and here stuffing boxes are necessary, although the motion will not amount to the one-hundredth part that of the trunnions of an oscillating engine. The bogies, furthermore, will be connected, as in all Mr. Fairlie's engines, by a framing through which to transmit the pull of the engine, without straining the boiler; and not only must this framing accommodate the pivoting motion of the bogies, but it must also directly bear a share of the weight. The success of the system will turn, we think, upon the strength, simplicity, and durability of the framing. We need not here describe it, as we have illustrated it in a former number of this journal. It certainly is less simple than the ordinary construction, and it presents points upon which questions might be raised as to fitting

and wear. But we hear that the quadrants, and their sliding blocks which connect the two bogies in one, have answered well in use: and it is clear that, should they fail to give satisfaction, a continuous framing might be employed to connect the bogies by their centres, and to transmit the weight to the centre of one bogie and to the sides of the other, thus carrying the whole upon three points, as in the North London and in all American engines. There need be no fear of applying the whole pull of one pair of cylinders through a properly made bogie centre. The continuous framing might be made to give great longitudinal support to the boiler, even if it did not distribute the weight at any point intermediate between the centres of the bogies. We have known very long fireboxes to be wholly unsupported by the framing, and to remain tight and strong; and we can see how a boiler made as in Mr. Fairlie's design might be supported without any undue strain upon two points 20 ft. apart. We have touched upon these few points of detail, not from any doubt that the principle of the double bogie engine may be worked out in the most complete and successful manner, but because they are in any case of great importance, and because even further improvements may probably be made in the plans, which, as now carried out in practice, give so much promise of good results."

51. On the subject of *Multi-Cylinder Locomotives*, the "Engineer" has the following article:—"It is not easy to resist the conclusion that the progress of improvement in matters concerning the construction of permanent way is greatly too slow to meet the requirements of a species of railway traffic which, whatever it might have been once, hardly deserves now to be termed abnormal. There is a growing tendency to force the railway system, at home and abroad, into all manner of impossible places. Curves and gradients which Rendel or Telford would have deemed out of place on a common road, are adopted without hesitation by the enterprising railway engineers of 1866, backed up as they are by the capital of yet more enterprising companies. We presume that in the long run such lines will be found to pay. They have for the most part a strong point in their favour in the fact that they are likely to be spared from competition. Under certain circumstances a railway is worth almost any sum, and we see little force in the arguments often urged against steep gradients. In-

deed, there is no reason why steam power should not be employed in haulage wherever a rail can be laid. But whether it can or cannot be employed economically, is quite a different question, the solution of which depends on the nature of the permanent way almost as much as on the construction of the locomotive. The load which a locomotive can haul invariably bears an obscure relation to the weight carried by the driving wheels of the machine, and in this fact lies one reason why heavy engines are required on steep inclines; and heavy engines are now being built with a sufficiently alarming disregard for all economical considerations regarding the maintenance of permanent way. It is tolerably clear, indeed, that in their construction locomotive engineers are drawing draughts on rails, sleepers, and ballast, which can only just be honoured now, and must ultimately be dishonoured. It was found out long ago that iron rails, laid on sharp curves, could not endure the tread of wheels with steel tires loaded to seven and even eight tons, yet loads as great as this have been rendered necessary to keep down the wheel base of engines required to conduct an excessively heavy traffic with absolute certainty, and they have provided the means of utilising the power developed in boilers of maximum size. Steel was introduced, and it was anticipated that steel would get over the difficulty. It is true that to a certain extent this anticipation has been realised, but the wear of rails is really only one item in the great bill of expenses incurred by the adoption of heavy loads on driving wheels. The hardness of a rail table is a very indifferent guarantee for the stiffness of the bar regarded as a girder. Possibly the best permanent way with which we are acquainted is that on the Metropolitan and its extensions, but its deflection under the tread of the 42-ton narrow gauge engines is something remarkable, especially on those sections where the line is on embankment. This deflection is not due so much to weakness in the rail as to want of solidity in the ballast, and of bearing surface in the sleepers; it represents a very considerable resistance all too seldom taken into account. In fact, substructure requires an improvement which it is apparently incapable of receiving as well as rails; and those who have most to do with road-making for heavy engines, best understand the difficulties with which they have to contend in the endeavour to impart

even moderate stiffness to permanent way as a whole. Again, where, as is invariably the rule in this country at least, two wheels of the same diameter keyed on one shaft are compelled to roll round a curve, the grinding resistance must increase at least in the ratio of the weight, and the fact that the rail may be of steel instead of iron affects the result very little if at all. The sleepers on sharp curves laid with steel rails may be seen glittering under this July sun with metallic fragments abraded from wheel and rail, and the crushing, tearing, ringing sound of a heavily-loaded wheel forcing its way through such curves as are to be met with anywhere within a mile or so of the metropolis tells but too plain a tale of mischief. The introduction of steel rails no doubt produces a direct saving in the expenses of railway maintenance, and, leaving the question of deflection untouched, this saving is regarded as about all that can be expected. It would be worth while, however, to institute a few experiments to determine the resistance per ton proper to engines carrying loads of from three to eight tons per wheel. In order to apply the tests properly the engines should be hauled at certain speeds, all the gearing being disconnected. While tested under steam—the power expended on their own propulsion being estimated from diagrams—it is obvious that so many sources of error may creep in that the results can hardly prove very valuable. We have reason to believe that the result would be greatly in favour of the light engine.

“From whatever point of view we regard this subject, the importance of reducing the load to be borne by the wheels—driving or carrying—of a locomotive, is apparent. It seems almost absurd to dwell on such a generally recognised fact for a moment; we presume there is not while we write, an engineer in Great Britain who does not regard heavy loads as evils, but it does not follow that locomotive superintendents or others are equally clear as to the means of mitigation to be adopted, or equally satisfied that any means of mitigation have a practical existence. Recognising the broad fact that certain loads have to be drawn and resistances to be overcome, they set about designing an engine to comply with the required conditions on well recognised principles, one of the most important of which seems to be that the locomotive superintendent should never take thought for the

permanent way. We do not for a moment dispute that the result is in the main satisfactory. We cannot just now call to mind a single instance in which an engine by an English maker failed to perform its stipulated duties, but a point has at length been reached which renders it necessary that many now old-fashioned notions should be abandoned, and that those who undertake to design engines should do so under the light of recent rather than antiquated experiences. Bury's four-wheeled engine was no doubt a very efficient machine in its day; but a mere development of Bury's engine would not suffice to produce a machine capable of working the future Metropolitan and St. John's Wood line, with grades of 1 in 25. Continental engineers long since recognised the fact that original treatment was required to adapt the locomotive to highly novel conditions of employment; and it cannot be doubted that much that they have done is satisfactory and rests on a sound basis; yet we should be sorry to find English engineers following them in the production of elaborate monstrosities, to the innate grotesqueness of which only the pencil of Gustave Doré could do justice. By the general adoption of a few very well known and simple expedients, and by a change in the general character of our designs, which, although radical and complete, would be by no means remarkable or strained, it would be quite possible to produce locomotives of maximum weight, and competent to discharge the most important duties, without doing more injury to, or demanding more strength in, permanent way than engines of almost the smallest type ever worked on an important line during the last thirty years, while in mere beauty of form they would lose little. The principle involved simply consists in the multiplication of coupled wheels. The fact that bogies or some other swivelling arrangement is also requisite, is due, not to weight in the engine, but to the existence of curves on the line; and strictly speaking bogies, or radial axle-boxes, are as necessary to light engines as they are to those which are heavy.

“It may be taken as a demonstrable proposition that the weight of an ordinary locomotive will provide adhesion enough to work up all the steam it can produce if all the wheels are drivers. It is clear that this law is not invariably correct. Thus, if it held true of an engine with 17 in. cylinder, 2 ft. stroke, and 8 ft.

wheels, it must be false of a similar engine with wheels of but 4 ft. diameter. Nevertheless, by a species of accidental coincidence, the proposition is proved by practice to accord with the truth roughly, yet closely enough to answer as a point on which to base an argument. We may also assume that practice has demonstrated it to be impossible, or at least unadvisable, to couple eight wheels. In this country it is hardly ever done now, although it has been attempted. Eight-coupled engines have also been tried on the Continent with very indifferent results. Many engineers hold that the resistance due to coupling increases as the square of the number of axles united, and we fancy the conclusion is consistent with truth. If, then, only four or six-coupled wheels of moderate diameter are to be used, it follows that to secure adhesion enough to work up the steam produced by an engine so large that eight or ten wheels are required to carry it properly, the drivers must support more than their share of the load. Thus the trailing wheels of some of the four-coupled tank engines on the South Eastern and London, Chatham, and Dover lines carry about sixteen tons; those of the narrow-gauge engines of the Metropolitan nearly as many. This is too much for economy on any road; yet, while we retain but a single pair of cylinders, it is impossible to reduce the weight to be carried by the driving wheels of large engines. There is no good reason why as much power as may be required should not be developed in a single pair of cylinders, or even in one cylinder, but there are many very excellent reasons against coupling a sufficient number of wheels to work up all the power which large pistons can develop, not the least of these being the difficulty of driving an engine with a long wheel base round curves. In one sense the multiplication of cylinders must be regarded as an evil, as adding to the weight, complication, and expense of a locomotive; but in another sense a second pair of cylinders must be looked upon as highly advantageous, in as much as their presence renders it possible to convert wheels into drivers, which otherwise must have remained uncoupled. All complexity is objectionable, but it is often necessary. Very many attempts have been made to provide coupling gear which would allow any reasonable number of wheels to be driven simultaneously, but without avail. Egerth's chain gear failed, and coupling rods fitted with ball

and socket joints have not come up to the expectations formed of them. A certain point once reached, a second pair of cylinders becomes the very best coupling expedient which can be used, and we have no doubt that it will ere long come into the favour which it really deserves with English engineers.

“On another page we illustrate a heavy engine designed by Mr. Fairlie, a gentleman well known for the invention of the twin engines, illustrated and described in our pages, now working successfully in Wales. The design forms an excellent illustration of the arguments which we have just used. In it we have an engine with a tremendous boiler, and wheels of moderate size. When full, the machine will weigh at least 50 tons, all of which are now available for adhesion. Were but two cylinders employed, the 50 tons must have been carried by six wheels, or, in other words, each wheel must have supported not less than $8\frac{1}{3}$ tons. As it is, the maximum load of each wheel is but 5 tons, which on a steel rail is practically harmless. It would have been impossible to arrange a 50-ton tank engine on a wheel base so short as that of the leading bogie, 8 ft. 9 in.; therefore the resistance going round curves would have been greatly increased. No one will, we think, maintain that the second pair of cylinders is here out of place, or that the engine we have illustrated would not be lighter on the road, easier round the curves, and better in every respect than any six or eight-coupled engine with single cylinders which could be produced of equal power. It may be urged of these engines, as it has been of those fitted with steam tenders by Mr. Sturrock, on Verpilluer's system, that the boiler will not produce steam enough for four cylinders. But this is simply a question of speed, and is really beside the mark. The question may affect a particular design, but cannot affect a general principle.

“It may be worth while to say here that Mr. Fairlie's faith in the twin system is as great as ever, and the design we now introduce to our readers (the reader is referred to the number of the Engineer for July 13th, 1866, for this) has been produced in order to meet a strong prejudice against side foot-plates, which it will require some patience to overcome. The present engine does not differ materially, as far as appearance goes, from certain tank engines now working the Great Northern Railway, which are

fitted with Adams' radial axle boxes, and a few engines recently introduced on the South-Eastern line which are fitted with bogies under the tanks. The general arrangement or combination of parts is, of course, the only novelty claimed, if we except details, which have been carefully enough worked out by Mr. Holt, the 'leading hand' in Mr. Fairlie's office. It will be seen from a glance at the plan that the coupling of the bogies with the frame is such that the boiler is spared all strains—no small consideration in the case of a machine capable of exerting a tractive force of over 20,000 lb., or more than eight tons. Two heavy slab girders running from end to end of the machine, indeed, impart immense stiffness, and in combination with the bogies spare the boiler much of the work to which it is ordinarily exposed. There are, no doubt, certain matters of detail in which the design admits of improvement, and we believe that this has been already effected; but after every exception has been taken, we think many of our readers will join with us in thinking that Mr. Fairlie's design satisfactorily embodies the most correct principle on which a heavy locomotive can be constructed. Great boiler power, large cylinder capacity, and small wheels, render it competent to get away with a heavy train without delay or hesitation; while its large weight for adhesion and the small load carried by its wheels individually render it very suitable for the exigencies of such an exceptional passenger traffic as that now worked on the North London and Metropolitan lines, or even the yet more remarkable conditions under which locomotives will be employed on the Metropolitan and St. Johns Wood and certain South American and Colonial Railways."

SECTION THIRD—MARINE ENGINES.

52. We here give part of a very able and suggestive paper from the "Engineer," on various points connected with *Marine Engines*:—"For some time past a species of lethargy has apparently fallen upon our marine engineers, and we now hear little of schemes which once attracted much attention and bid fair to revolutionise the practice, if not the science, of marine propulsion. It may possibly be demonstrated, however, that the marine engineer has not been asleep; that so far from having

sunk into lethargy he has been actively yet quietly carrying out important experiments; and that the fact that superheating, high pressure, and surface condensation are not so freely discussed as they were six or seven years ago, is mainly due to their having gradually assumed their own level, and taken their proper place in the estimation of sea-going engineers and ship-owners, by whose verdict manufacturers must be more or less influenced. Still there are certain prominent improvements to be noted, and of these one of the most important is the progressive increase in the actual as compared with the nominal horse-power, especially of engines supplied to her Majesty's navy, during the last few years. First-rate builders are now not satisfied unless the actual is at least six times the nominal power, while not very long ago a proportion of four to one was considered good work. It may of course be urged that nominal power means nothing, and that therefore the statement that a pair of engines of 800 horse-power gave 4,800 indicated horse-power on a trial trip may imply no real excellence whatever. But it is easy to see that the term nominal horse-power has much to do with the weight of the machine, and thus for a given weight we get more power now than we did formerly. It matters nothing that engines by different makers show a remarkable disparity in this respect—Messrs. Penn and Son using 6 as a factor of safety, we believe, while Messrs. Maudslay and Field use 12, and other makers various proportions between the two.—A rule once adopted by an eminent firm is usually adhered to pretty closely; and thus we may take it for granted that although a modern engine by Messrs. Maudslay, for example, of a given nominal power, is heavier than an engine by Messrs. Penn of the same power, it will give a higher indicated power than an old-fashioned Maudslay engine; and a modern engine by Messrs. Penn will, in turn, give out a greater force than one of their older engines. Thus, when speaking of improvement, we do not mean to say that any very remarkable change has been effected in the general principles controlling preparation or designs, or that any one firm has recently improved upon another's ideas. On the contrary, makers have improved upon themselves; and in order to measure the degree of this improvement, those interested must institute a comparison between the past and the present work of particular

firms, not between the work of distinct establishments. The increased efficiency to which we have alluded is due principally to the adoption of higher piston speeds and larger measures of expansion. More care is taken than formerly to supply the engines only with dry steam; and cylinders are now jacketted and clothed with heretofore unusual caution. Expanding steam is very liable to condensation by the least deprivation of heat; but such precautions are now taken to keep up its temperature while developing its energy, that the condensation even with grades of expansion as high as six, is actually less than was the case when steam was worked nearly full stroke. By the aid of surface condensation, again, higher pressures are carried, which tend of course to increase the actual as compared with the nominal power of the marine engine. But the surface condenser has not yet become thoroughly popular, nor is it likely to enjoy complete confidence for some years to come. It is still highly questionable whether its use prolongs the life of a boiler even when a small quantity of salt water is admitted with the feed; and it is certain that without this admixture, boilers worked in conjunction with surface condensers are quickly destroyed. A marine boiler, if carefully worked with injection, will last about six years on an average, or perhaps a little more; and we are not aware of the existence of a sufficient number of marine boilers worked with surface condensers for greater periods and still remaining serviceable, to establish the principle that with condensed water they will last longer. The matter still remains in doubt, and will probably remain in doubt for two or three years. A sufficient time, indeed, has not yet elapsed since the introduction of the mixed feed system to enable its merits to be thoroughly tested. The principal value, however, of the surface condenser lies in the fact, that by its aid fuel may be economised; and even were it certain that boilers were always worn out more rapidly by its use, still this saving is sometimes sufficiently great to render it clear that no loss whatever would be thereby incurred—the outlay in the matter of boilers being repaid by the saving in fuel. Yet it must be remembered that laying up a large ship to effect extensive repairs entails a serious loss, and this circumstance has gone far to retard the replacement of the injection by the surface condenser.

“Very little progress has been recently made in the introduction of high pressure at sea, notwithstanding the substitution of distilled for sea water as feed. It is true that 50 lb. pressure has been, and we believe is still, used in a few instances; but a pressure 10 lb. to 20 lb. less than this may be taken to represent the maximum ordinarily used. It is somewhat curious that this pressure almost exactly tallies with the temperature, at which, according to Cousté's experiments, all the deposit is thrown down, and thus the maximum amount of mischief which can be wrought by pressure effected. By raising the pressure from 20 lb. to 40 lb., the amount of deposit thrown down in a given time will be greatly augmented; by raising it from 40 lb. to 80 lb., however, the quantity will hardly be appreciably increased. In a word, 40 lb. pressure once reached, it would appear that we may go as much further as we please without having much to fear on the score of deposit. Indeed, it is a mistake to conclude that the fear of deposit alone restrains marine engineers from high pressures. The reason that they are not adopted is based on two principal propositions. The first is, that a boiler explosion at sea must be infinitely more calamitous than one on land, inasmuch as it would lead to the total loss of ship, cargo, and passengers; and the second, that no very suitable form of boiler capable of withstanding high pressure has yet been invented, all the parts of which shall be readily accessible for cleaning and repairs. The external configuration of the ordinary return tube marine boiler is eminently suitable to a position within the hull of a ship, and on this circumstance half its popularity depends. The cylindrical generator, whether horizontal or vertical, is not well adapted to the hold of any ship, but it is difficult to design a good boiler, not circular, capable of withstanding 100 lb. steam, say, and still possessing large water and steam spaces. Engineers, therefore, still hesitate to adopt excessive pressures, and properly so. But we may point out that the individual who can produce a really good marine boiler capable of enduring a high pressure, and yet suitable in contour to the hold of a ship, will deserve well of his countrymen. Many attempts have been made to adopt high pressure at sea, but, from various causes, these have all ended in disappointment, possibly because those who tried them expected too much, or did not properly avail themselves of the advantages

placed at their disposal by the use of high steam. It is hardly to be doubted that a good deal in the way of blundering has been accomplished in this direction; and it is possible that were some of our most eminent firms to attack the subject once more, aided by the light of experience gathered during the last few years, much good might be effected and greater advances made than now appear possible. High pressure is especially valuable at sea, as it permits steam to be fully expanded in engines of moderate size and weight, and it is really to be regretted that having gone so far as 40 lb., and thus encountered the worst that deposit can do, even with the injection condenser, we do not go further, and carry 60 lb. to 80 lb. steam expanded in small cylinders behind pistons running at high velocity. Of the economy of such practice there can be no question. The difficulty lies in reducing what is now more or less theory to practice."

53. *Maudslay and Field's Three-Cylinder Engine*.—"The value," says the "Engineer," "of using steam expansively has now become generally recognised, and our principal engineers vie with each other in the endeavour to produce economical machinery. For years compound engines have been in favour for the carrying out of the principle of expansion to its greatest limits. We have had the cylinders located side by side and end to end. Annular pistons have also been patronized. The great defect of the compound engine is its complication, and the difficulty of obtaining access to its parts for repair. Its great advantage lies in the fact that the temperature of the steam is maintained at a higher point during the first steps of expansion than would otherwise be the case. Messrs. Maudslay and Field have long held that for all practical purposes expansion is best effected in a single cylinder within which its work begins and ends; and the firm has produced a peculiar type of engine fitted with three cylinders, which is well known, and has given excellent results. The engraving on page 10 (not given here; the reader is referred to the number of the 'Engineer' for Jan. 5th, 1866, for it) represents a set of engines of this kind, almost identical with that fitted on board the Octavia, of which mention has often been made in our columns.

"The valve gear is the most remarkable feature in the design of these engines. The slide valve is so arranged as to effect the cut-off without the aid of an independent valve, the maximum

grade of expansion being one-seventh, the minimum one-third. The entire gear has been invented and patented by Mr. Sells, one of the principal functionaries in the managing department at Messrs. Maudslay and Field's. An engraving of the slide valve will be found in the 'Engineer' for August 4, 1865. The stroke of a slide valve is determined by the outside lap and the widths of steam openings proper to the slide. Now, with wide openings and early grades of expansion the outside laps are considerable. Cognisant of this fact, Mr. C. Sells eludes the universal attendant evils of long-stroke valves by increasing the number of the ports, and thus decreases the outside lap in proportion. The habitual means of reversing the action of the valves of marine engines is the well-known valve link motion. The raising and lowering of the link has been—and still exists—a halting point amidst the general advance of improvements. Mr. Sells gets rid of the ordinary mode of starting, reversing, stopping, and expansion gear, by the introduction of serial spur gearing. Above the main framing and secured to the same, a standard, which is a guide for the valve rod, supports the motion shaft, and forms a stationary link or slot. At the same time the first spur wheel (shown as a dotted circle) is secured on the crank shaft; the second wheel gears into the third, each of the two last revolving in their bearings, either from the motion imparted by the first wheel, or by the raising and lowering of the frame supporting them. The fourth spur wheel is secured on the motion shaft; by this it will be understood that the two outside wheels are merely transmitters of motion. The shifting portion supporting the gearing is secured to a block—working in the slot—at the one end, and to the starting lever at the other. The motion, as shown at present is up, or at the highest point. When it is required to reverse the engines the action will be as follows:—The starting wheel imparts motion to the shaft of the same, mitre gearing on the horizontal and perpendicular shafts raises and lowers the lever connection by a screw on the rod of the same, and the lower mitre wheel acts as a stationary nut, as far as progressive movement is affected. The starting wheel thus affects the whole motion by its action. The mitre gearing raises the connecting loop, the lever lowers the intermediate gearing support, but the upper end moves in the direction of a radius

whose centre is the motion shaft. It will, doubtless, have been noticed that the wheels are of equal diameters, hence, whatever be the distance the motion shaft is moved, the position of the lower loose gear will be the same in relation to that fixed on the crank shaft; this is shown by the dotted angular and curved lines. The wheel on the crank shaft can be regarded only as the imparter, not the reverser, of the motion required. The intermediate wheels affect the position of the slide by their connection, or rather angle of contact. The alteration of the position of the slide can, then, be due only to the shifting of the intermediate gearing, acting with, or rather giving motion to, the valve motion shaft; half a revolution being either gained or lost in relation to the motion of the main shaft, according as the idle wheel frame is raised or lowered. The type of engines is that known as the double piston-rod return connecting-rod. The piston-rods of each engine pass over and under the crank shaft, and are connected to a crosshead, secured in a guide block of the letter U shape; the connecting rod is single at each end, and adjusted in the ordinary manner. The guide for the block is of the single V-shaped kind, located under the centre line of action. The feed and bilge pumps receive their motion direct from the piston-rod cross-head—the centre engine, being the imparter of motion. The condensers are two in number, located outside the guides of the fore and aft engines. The class of condenser is that of the internal tubular surface kind; the tubes are arranged at an angle having a rake or inclination of 2 in. per foot. The steam enters the condenser at the end nearest the crank shaft centrally of the tube plate, before passing through the tubes, condensation has ensued and the liquid is drained from the receiving chamber and forced into the feed-water tank seen at the end of the feed and bilge pumps. Doors for access of repair, cleansing, &c. are secured at each end of the condenser; the air pump receives its motion from or by an inverted projection keyed on the outer piston end: this pump is double-acting, with the usual india-rubber valves suitably located. The circulating pump is double-acting also, located between the condensers, receiving motion from the steam piston. The supply pipe is at the side of the feed-water tank, and the discharge passes over the guide, cross-head, and connecting-rod. The final discharge of the water after

surrounding the tubes is at the top of the condenser at the back end of the same. The tubes are of the ordinary kind, packed at each end with india-rubber. The arrangement of the supply steam pipes can be readily understood on referring to the full page illustration. The arrangement of the engines is, perhaps, not entirely conducive to economy of space, but the attainment of the reduction of the consumption of the steam in proportion to the ordinary kind is certain. The indicator diagrams, taken from engines of this type, fully bear out the intention of the inventor and constructors. The certainty of an uniform motion with three separate cranks is an advantage mooted long ago, but the practical application of the proposal must be credited to Messrs. Maudslay and Field."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION THIRD, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

- Engines, &c. (High pressure), for Steam Launch*,—Engineering, Nov. 9th, Illus.
Benson's Slide Valve,—Engineering, Nov. 9th, p. 360, Illus.
Hay's Surface Condenser,—Engineering, Nov. 16th, p. 374, Illus.
Four-Cylinder Locomotives,—Engineering, Nov. 16th, p. 369.
Blowing Engines at the Lillieshall Ironworks, Shropshire,—Engineering, Nov. 16th, p. 370, Illus.
The Yorkshire Engine Works,—Engineering, Nov. 16th, p. 371.
Horizontal Engine and Patent Pump for pressing Cotton, by Robinson and Cottam,—Engineering, Nov. 16th, p. 378, Illus.
Express Locomotive for the Grand Central Railway of Belgium,—Engineering, Nov. 16th, p. 378, Illus.
Locomotive Chimneys,—Engineering, Feb. 23d, p. 122, Illus.
Locomotive for the Mont Cenis Railway,—Engineering, June 5th, p. 8, Illus.
Marine Engines,—Engineering, Feb. 2d, p. 78.
Expansive Working,—Engineering, April 6th, p. 214, Illus.
Portable Engines, Ingram and Philips's,—Engineering, June 15th, p. 398, Illus.
Rollers for Slide Valves,—Engineering, May 18th, p. 323, Illus.
Davis's Piston Valves,—Engineering, June 22d, p. 411, Illus.
Small Wheeled Tank Engines,—Engineering, June 22d, p. 420.
Equilibrium Slide Valves,—Mech. Mag., March 2d, p. 140. Also March 9th, p. 155.
Engines of H.M.S. Agincourt,—Engineering, Feb. 16th, p. 100, Illus.
Engines of the Steamer Ladyburn,—Engineer, Sep. 21st, p. 210, Illus.
Cut-Off,—Mech. Mag., Jan. 12th, p. 23.
Tank Locomotive, South-eastern Railway,—Engineering, Sept. 7th, p. 170, Illus.
Expansion and Propulsion,—Civil Engin. and Architec. Journal for Feb.

- The Brooklyn Pumping Engine*,—Engineering, April 20th, p. 250, Illus.
The Corliss Engine (Inglis's), „ Aug. 10th, p. 96, Illus.
Heavy Goods Engine for Steep inclines by M. Thouvenot,—Engineer, Jan. 26th, p. 68, Illus.
Quick Running Engines,—Engineer, Sept. 7th, p. 182.
Oscillating Engines for the Emperor of Abyssinia, by Easton and Amos,—Engineer, Oct. 20th, p. 313, Illus.
200 Horse-power Pumping Engine, New River Waterworks, by James Watt & Co., Soho,—Engineer, Oct. 20th, p. 316, Illus.
Expansion Gear,—Mech. Mag. Jan. 26th, p. 54, Illus.
Engines of the U. S. Monitor Steamer Monachnock,—Engineering, June 22d, p. 413, Illus.
Horizontal Engine with Piston Valve,—Engineering, Sept. 21, p. 204, Illus.
Darby Blowing Engine, Ebbw Vale Ironworks,—Engineering, Sept. 7th, p. 100, Illus.
Miniature Yacht Engine,—Engineering, Sep. 7th, p. 163, Illus.
Engines of the Steamship Perenè and Ville de Paris,—Engineering, Aug. 31st, p. 156, Illus.
Engines of the Twin Screw Steamship Cosmos,—Engineering, Oct. 20th, p. 313, Illus.
1000 Horse-power 3 Cylinder Engines, for H.M.S. Iron-clad Lord Warden,—Engineer, June 29th.
Rotative Pumping Engines, Lambeth Waterworks,—Engineering, Oct. 12th, p. 273, Illus.
Blowing Engines,—Engineer, Oct. 12th, p. 267, Illus.
250 Horse-power Direct Acting Pumping Engine,—Engineer, Oct. 12th, p. 274, Illus.
Cornish Pumping Engine, 400 Horse-power,—Engineer, July 27th, p. 64, Illus.
Fairlie's Engine for Heavy Goods Traffic,—Engineer, July 13th, p. 24, Illus.
Direct-Acting Blast Engine, Stanton Ironworks, Derby,—Engineer, Oct. 19th, p. 290, Illus.
The Value of Steam Engines,—Engineer, April 20th, p. 289.
Ericsson's Engines in the U. S. Turret-ships,—April 20th, p. 206, Illus.
Double-Cylinder Pumping Engine, Chelsea Waterworks,—Engineer, Oct. 5, Illus.
Crossness Pumping Engines,—Engineering, March 9th, p. 150, Illus.
The Machinery of the Winaus Yacht (Cigar Ship),—Engineer, March 9th, Illus.
Balanced Governor Valve,—Scientific American, p. 2, vol. 1866.
Locomotive Connecting Rods,—Practical Mech. Journal, June, Illus.
The "Tiny" Locomotive,—Engineering, Jan. 19th, Illus.
American Portable Engines,—Engineering, Aug. 10th, Illus.
Siemens' Gyrometric Governor,—Engineering, April 13th, Illus.
Engines of the American Sloop of War "Hassalo",—Engineering, Sep. 21st, Illus.
Heavy Tank Engines,—Engineering, March 2d.
Mountain Locomotives,—Engineer, Nov. 2d.
Express Engines,—Engineering, Feb. 16th.
Notes on Locomotives,—Engineering, July 6th.

- Expansion Ferrule and Cap for Boiler Tubes*,—Pract. Mech. Journal, Jan. 1st, Illus.
- Standard Steam Fire Engines*,—Engineering, Sep. 28th, Illus.
- Twin Screw Engines*,—Engineer, Sep. 28th, Illus.
- Three-Cylinder Expanding Engines (Marine)*,—Engineer, Jan. 5th, Illus.
- Blowing Engine at the Ebbw Vale Ironworks*,—Engineer, Sept. 14th, Illus.
- Experiments on the Friction of Leather Bottoms in Hydraulic Cylinders*,—Engineer, June 1st, Illus.
- New Blowing Engine*,—Engineer, Jan. 12th.
- Fairlie's Locomotive*,—Engineering, March 23d, Illus.
- American Marine Engines*,—Engineering, March 23d.
- The Corliss Engine*,—Engineering, March 2d, p. 237.
- On Simple Rules for Practical Calculations of the efficiency of Steam*,—Engineer, Jan. 5th.
- "Vacuum" and the Indicators*,—Scientific American, May 5th, p. 296.
- Our Position on the Expansion Question*, ,, ,, Jan. 20th, p. 55.
- Counter-Weighting Machinery*,—Engineer, Feb. 16th, p. 128.
- The Law of Progress and the Steam Engine*,—Mech. Mag., Aug. 24th, p. 118.
- Locomotive Engines*,—Engineering, Sep. 21st, p. 206.
- Heavy Goods Locomotives*,—Engineer, Jan. 5th.
- Counter-Weights on Locomotives*,—Engineering, July 20th, p. 49.
- Locomotive Traction*,—Engineering, Jan. 19th.
- Notes on Steam Vessels*,—Engineering, Aug. 3d, pp. 88, 106.

DIVISION FOURTH.

MOTIVE POWERS OTHER THAN STEAM ENGINES,—AS GAS, &c.

54. *Gas Versus Steam*.—Under the above title the "Mechanics' Magazine" gives an able article which we do the reader a service by re-producing in extenso here:—"Air and water are the two natural and original motive powers bestowed upon man, and, until very recently, were the only forces at his disposal for the production of motion on a large scale. With the introduction, or, more correctly, with the successful application, of steam as a motive power, came a complete revolution in the radical principle of mechanical appliances. Windmills and watermills were, by all those who could afford the innovation, either doomed to peremptory destruction, or consigned to the equally sure though slower process of decay. Many having even until now survived

the effects of the inevitable *tempus edax rerum*, remain as standing examples of what may be now termed mechanical scarecrows. In several instances this wholesale abandonment of a power almost irresistible in favour of an expensive substitute betrayed a lamentable want of judgment and a reckless disregard of economy. It also led to a complete neglect—in fact, to almost an utter unconsciousness—of the immense water power stored up in some of our mountain rivers and their tributaries. It is certain that, were the poet's description of a stream, "*labitur et labetur in omne volubile ævum*," capable of a wide and extended application to rivers in general, particularly to the depth, water would never have ceased to hold the first rank as a motive force. It is now, however, quite ignored as such in principle. In the cases where it is still in operation it is not employed, like steam, for the sake of its theoretical or mechanical principle, but solely on account of the peculiar and isolated advantages attendant upon the particular locality. It is otherwise with its originally co-existent power, air, which, although it suffered in its reputation, so to speak, from the same cause, has nevertheless retained all the *vis vitæ* of a true mechanical motor. The construction, now in progress, of the Pneumatic Railway from Waterloo to Whitehall is a proof that it is capable of rivalling steam in its most prominent features of mechanical subserviency. The difference between the two powers, air and water, as motive agents, may be briefly summed up as follows:—The former is general, certain in action, can be obtained everywhere, and used everywhere. The latter is particular, variable, and uncertain in action, can be obtained only in special localities, and used to advantage only in those localities. The result is, that one has died out, while the other, after undergoing a temporary abandonment, and even failure—the Atmospheric Railway, for instance—has been revived, and its future application as a successful motive power is at present being carried into effect.

“All explosive substances of a solid nature owe their tremendous effect to the rapid—in reality, almost instantaneous—formation of a highly expansive gas, which is set free at the moment of explosion, and the elements of which existed in a neutral or quiescent state in the body previously to the application of the means, generally fire, necessary to bring about the

explosion. Sometimes the gas exists in the gaseous state in the material, and is only retained by mechanical means, such as a great pressure. An example of this is presented by what are called 'fiery seams' in coal mines. An immense quantity of gas is frequently held pent up in these seams, and has been so probably for ages, only requiring, like the winds of King Æolus, to be permitted to escape in order to carry ruin and devastation to everything within the reach of their destroying influence. Thus it happens with the firedamp: directly the seam is tapped the controlling pressure is removed; eager for escape from its long imprisonment, out bursts the expansive fluid, joyfully welcoming the first spark of fire it may encounter, and the annals of our colliery accidents can furnish innumerable examples of the disastrous and deplorable results of its too sudden liberation. At other times the elements of the gas do not enter into combination until a chemical change takes place in the constitution of the substance itself. A familiar instance is afforded by gunpowder, which in another point of view deserves notice at our hands as bearing upon our subject. The point to which we would refer is, that various experiments at different times have been undertaken with the hope of rendering an agent so powerfully destructive fit for other purposes than those of warfare and blasting. It is quite clear that by the introduction of small charges of gunpowder in a cylinder in a manner analogous to that of steam and exploding them, an alternate motion could be imparted to a piston and all the usual mechanical effects of steam produced. We have not space to record all the failures, and sometimes partial successes, which have attended these experiments. There is one great and important distinction between the result of the explosion of a gas which is formed by the disintegration and separation of the component elements of a solid body, and of that caused by a gas, whether simple or compound, which exists in the gaseous condition previously to explosion. In the former case there is almost always a solid residuum, in the latter there is rarely any. The residuum of gunpowder gives rise to what is known as the fouling of a gun, which is obviated in gunnery by sponging and other ordinary means. When, however, we consider what the effect of any solid residuum would be upon the interior surface of a cylinder traversed incessantly by a piston, the

unequal wear and tear, and the continual trouble and expense of either supplying new cylinders or having the old ones rebored, we are forced to admit that, apart from other practical difficulties and objections, this is not quite the field for a motive power such as gunpowder. Independently of the practical proof that gunpowder leaves a deposit after explosion, this truth may be readily inferred from its chemical constitution. Employing symbols we have gunpowder expressed by the formula $K O, N O^5 + S + 3 C$. The action which ensues on the application of fire and the chemical constitution of the different gases and of the deposit are explained by the equation $K O, N O^5 + S + 3 C = K S + 3 C O^2 + N$. The enormous force thus developed is principally due to the volume of nitrogen set free, the high temperature—about 2,160 deg. Fah.—materially aiding its expansive power. The carbonic acid which is also formed lends its assistance towards the explosive effects. On the assumption that a charge of one cubic inch of gunpowder were employed, the volume of the mixed gases generated would equal about three hundred and seventy cube inches on explosion.

“The employment of gas in lieu of steam has been frequently tried in America, on the Continent, and in this country. Until recently the experiments do not appear to have led to any very great practical utility. The invention and gradual introduction of the Lenoir gas engines have solved all doubts respecting the feasibility of substituting gas for steam on a small scale, and with, apparently, the most satisfactory results, regarding economy and other important considerations. The Lenoir gas engine is very similar in design and principle to Drake’s engines, which were tried a few years ago in America, but failed to come into extensive use, principally from the high rate of gas at that period. The chief difference between them consists in the mode of exploding the gas inside the cylinder. In Drake’s engine this was accomplished by subjecting the gas to the actual contact of a piece of red-hot metal, while, as will be presently seen, the ignition is effected in the Lenoir engine through the agency of the electric spark. Before turning our attention to the actual merits of the patent gas engine, and the probability of its superseding steam in its general application, the following brief description will be interesting:—‘The Lenoir patent gas engine resembles

in its general appearance a horizontal steam engine, having cylinder, piston, crank shaft, and flywheel, with the usual gearing for distributing the motive power. The cylinder has the necessary slide arrangements for the admission of coal gas and atmospheric air in the proportions of one of the former to ten of the latter, which are ignited inside the cylinder at the proper moment, in the following manner. Two of Bunsen's constant batteries are put into connexion with Ruhmkorff's induction coil, whence the current is conducted by two insulated wires to a distributor of electricity placed on the crank axle. The reciprocating motion of the piston alternately makes and breaks the electrical connexion between this distributor and the "inflammateurs," which are placed inside each disc of the cylinder, and fire the gaseous charge at each stroke of the piston. The products of explosion are carried off by a waste pipe connected with the valve-box, while the cylinder is surrounded by a water-jacket to prevent the temperature becoming excessive.' To the minds of those who regard any new machine or mechanical invention in the light of other than a mere commercial or interested point of view, the question which presents itself on the introduction of a novelty is, to what will this principle probably attain? With respect to the Lenoir engine, will it take the place of our large stationary engines? will it supersede our locomotives? in a word, will gas become a substitute for steam? We answer, No. It is possible that the success which has attended these engines in their present limited application has prevented those principally interested in its future development from making any very extensive experiments, and incurring expense which might be unprofitable, in attempting to adapt it to the purposes of a locomotive. Some experiments have been undertaken in furtherance of this object, but they failed to give any fair promise of ultimate success. Probably they were not conducted on a sufficiently large scale. The chief difficulty to be overcome was found to be the loss of power in getting past the dead points. It must have struck anyone who has seen a Lenoir engine at work what an enormous proportion the flywheel bears to the horse power of the engine. The very principle of the machine necessitates this disproportion. In the cylinder of the ordinary steam engine, the steam commences to act upon the piston the moment it enters the cylinder,

both by virtue of its initial pressure, and its own expansive force. Advantage is taken of the latter quality in all engines worked on the expansion principle, in which the steam is cut off after a certain proportion of the stroke has been accomplished. The dead point may be defined for steam engines as that position of the crank in which the pull or thrust of the piston rod, accordingly as the stroke is forwards or backwards, is in the same horizontal plane as the longitudinal axis of the crank axle, and, consequently, the tendency of the crank to rotate is reduced to zero. Were it not for the momentum of the flywheel, which carries the crank past this dead point, the machinery would break in pieces. On the other hand, in all engines whose motive power is obtained through the agency of an explosive mixture, such as the Lenoir, the whole of the gas necessary for each stroke enters the cylinder before it is ignited, and it exerts no sensible pressure upon the piston until it is ignited. It follows from this, that while in an ordinary steam engine the duration of the action of the flywheel, or the duration of the dead point, continues for only an inappreciable portion of the stroke, in the gas engine it lasts for about a third, and hence the increased weight of the flywheel. In small stationary engines a larger flywheel than usual does not much signify, provided compensating advantages are obtained. The case, however, is altered when we increase the dimensions and power of the engine.

“The loss of effective power combined with the intermittent action of all explosive forces, which may have no practical importance on a small scale, may be found to be attended with decided disadvantages when applied on a large scale. The application of the Lenoir engine to the purposes of the locomotive, where the flywheel is replaced by the double cranks and cylinders, appears from the above and other reasons to present very considerable and almost insuperable difficulties. Another serious obstacle to be surmounted in adapting gas engines for heavy work is, that any increase of power is only obtained by a very disproportionate increase in the size and capacity of the engine. In a locomotive, for instance, we can use nearly the same quantity of steam at different pressures and so vary the power as required. Moreover, a very small increase in the size of a locomotive will give a considerable increase of power. The power of a steam

engine depends not so much upon the volume as upon the pressure of the steam used. In the Lenoir engine the power depends absolutely upon the quantity of gas which can be admitted into the cylinder. As the maximum effect of the explosive force of the gas is obtained solely by preserving the due proportion between the coal gas and air, it is manifest that the capacity of the cylinder soon puts a limit to the power of the engine. The capacity of the cylinder of a gas engine replaces, in fact, the strength of the boiler of a steam engine. The volume of the one is the pressure of the other. We do not concur with the opinion of the patentee in pronouncing explosions (otherwise than the orthodox ones) impossible. On the contrary, they are quite possible. We are not given to timidity, particularly in scientific matters; but next to Berthollet's fulminating compounds of gold and silver, we can scarcely imagine more dangerous elements for the production of a motive power. The contact of coal gas and air has given rise to some of the most frightful explosions on record. We are quite ready to admit that, in the small specimens of the Lenoir engine in present use, an explosion is extremely improbable, and if it did occur, would not be attended with any other result than a temporary inconvenience. We cannot vouch so much, supposing the engine were on a very large scale. The explosion of a few grains of gunpowder would not probably cause any serious injury, but the explosion of a pound weight would be a different affair altogether.

"It cannot fail to attract the notice of the most superficial observer that many and costly accessories, sometimes on a stupendous scale, are necessary for the production of a large amount of steam power. Take the engines at Crossness Point, the southern outfall of the metropolitan sewage, as an example, with all their boilers, furnaces, fittings, chimney shaft, pipes, and a multitude of other expensive accompaniments, complicated both in their nature and mode of action. The ruling principle of simplicity is widely departed from in the case of steam power. In the description of the Lenoir engine, it was mentioned that the combined gases are fired by means of the electric spark, and it is worth remarking that an agent so wonderful and powerful as electricity should be made to act a subordinate part in a machine, when it is a mere question of time for the subordinate to usurp

the place of the principal, and to surpass not only it, but also its rival, the steam engine. Electricity is the vital essence of matter. No portion of matter exists without it, and it cannot exist except as a portion or a condition of matter. In some substances it is more easily excited than in others, and they are what are called conductors of electricity. Non-conductors are substances in which electricity exists to an equal, perhaps to a greater, degree than in conductors, but which it is difficult to excite; it appears to lie dormant as it were, and is not roused except by a very powerful force. Before electricity becomes the motive power it is ultimately destined to be, many of the bodies at present deemed non-conductors will have to be proved conductors, for, until we can obtain sufficient intensity and strength of charge to excite the electricity in many bodies at present scarcely susceptible of such a process, we cannot expect to turn electricity, whether fractional, voltaic, or magnetic, to any important mechanical advantage. From the experiments which have been made it is probable that electro-magnetism will be the peculiar state in which the motive force will operate. From what we have ourselves seen of the Lenoir engine we consider that for all purposes where no greater power than from 5 to 6-horse power is required, it bids fair to supersede the steam engine. It might not be inaptly termed the drawing-room engine, being perfectly free from all disagreeable accompaniments. All that is necessary is to connect it with any ordinary gas-pipe, make the connection with the battery, give a half-turn to the flywheel, and the engine is started. A governor is generally attached to these machines, chiefly because people like to have them. They clearly fancy they are the correct thing to have. In reality the governor is useless, as a consideration of the principle upon which the machine works would point out. At all large country residences and seats, this machine might be economically employed for a variety of domestic purposes, particularly as gas is generally manufactured on the premises. Whenever gas is specially made for the engine, the fact should be borne in mind, that gas inferior in quality to what is employed for house-lighting may be used. It is not required to possess either the purity or illuminating properties of the ordinary gas. Copper pipes should be eschewed, as acetylen, one of the numerous ingredients of coal gas, forms

an explosive compound with that metal, and some serious casualties have occurred in consequence. We have before mentioned that we do not believe that the amount of power necessary to work an engine on a large scale could possibly be generated by a Lenoir or any other gas engine ; but, at the same time, we have seldom seen a machine so thoroughly answering the purposes it professes to accomplish."

55. *Heated Air Engine*.—"The peculiarity of this engine is this," says the "English Mechanic :"—"It does not use upon the piston, heated air alone, but the products of combustion also ; the air to supply oxygen for the combustion of anthracite coal, so pumped in by pump (D), the carbon is burned rapidly and completely under pressure, and the resulting carbonic acid gas, from the air, are passed from the generator, or fire-box, to the piston. The piston is in the form of a hollow plunger moving in the cylinder (A), so arranged that it is fitted and packed only at the top, where there is the least heat.

"In this arrangement the common difficulty of lubricating a hot cylinder and burning-out packings is obviated. The fire-box (G) inside is surrounded with heavy fire-brick and soap-stone, which prevents burning out the iron, also radiation of much heat into the room. The engine is single-acting.

"The cut represents a two-horse power engine ; the diameter of the pump is 12 in. ; that of the piston 16 in. ; and the difference in the area of the pump and piston, multiplied by the usual pressure, eight pounds to square inch, shows that the engine exerts a two-horse power ; yet with good anthracite coal (and no other should be used), good care and good fire, it can do at least three-horse power.

"It requires about 8 lbs. of hard coal per hour, or about one ton per month, and some twenty minutes' attention, to keep it in working order ten hours.

"The larger and smaller engines require corresponding expense. The speed is regulated by a governor, and the amount of power by dampers, which pass the air through or over the fire, as is required.

"It occupies a space six feet square (a common stove pipe and ordinary flue being all the draught arrangement required.) The pipe may be run round the room in cold weather and save the use of stoves.

"They can be used in agricultural work, or on boats, and for pumping, and it is intended to fit them on wheels expressly for such uses.

"In using these engines, says the inventor, there is only one great important thing necessary to be observed; and that is to keep them perfectly clean. Every night, after it cools, it should be wiped inside the cylinder and pump, as well as bearings, perfectly clean, so that there shall be no substance from the oil and dust, to harden by the heat and create friction; also, there should be a fresh fire every morning. Wood should not be used except in kindling fire. With these cautions closely observed (and no accident) parties have not to exceed 20s. per year for repairs the whole time.

"There are some hundreds in use in America, driving shoe machinery, printing presses, saws, machinery, hoisting, pumping, turning, meat cutting, &c. &c."

56. *Water-Pressure Engines*:—"The use of water pressure as a means of obtaining power," says a writer in the "Engineer," "has attracted comparatively little attention hitherto. It is true that the turbine is, in a sense, impelled directly by pressure; but we now speak more particularly of those machines in which a piston is impelled by the pressure due to a lofty column of water. The attempts which have been made to thus develop power have not been very successful, with a few exceptions, in a commercial point of view, possibly because the greater proportion of those who require power are not aware of the capabilities and advantages of such machines when well made and skilfully designed. Sir W. Armstrong has done more than any other engineer, past or present, to introduce a motive power which is really economical, cleanly, and convenient in no ordinary degree. In recent numbers of the *Engineer* we have described—and we have been the first to describe—the most recent arrangements which he has adopted in working cranes. We have also been favoured with a drawing of his water-pressure engine, fitted with his latest improvements, which we hope to be able to lay before our readers in a short time. But Sir W. Armstrong is not alone in the field now, and the subject is beginning to receive the attention it really deserves from many practical engineers. Water-pressure engines have a certain sphere of usefulness, and if pro-

perly constructed they can be made to yield a very high percentage of duty. Unlike the turbine, when their speed is reduced in consequence of an overload the volume of water consumed is proportionably reduced, and although, as compared with steam, the velocity of water is low under equal pressure, and water-pressure engines therefore require more capacious pipes and valve apparatus than would suffice for steam, yet with due care every necessary condition may be fulfilled, and a very high velocity of piston may be obtained without shock or strain.

“Among the labourers in this field who deserve considerable credit, and have attained a fair amount of success, must be classed Messrs. John Ramsbottom & Co., of Blackburn. Mr. Ramsbottom has courteously placed at our disposal tracings from the working drawings of the water-pressure engine shown in the engravings, (the reader is referred to the number of the ‘Engineer,’ under date May 4th, 1866, for these drawings, which space does not admit of our giving here). These engines are of moderate size, commencing with pistons but 2 in. in diameter for great pressures, and are principally intended for the use of small consumers of power residing in towns, with a high-pressure service; but it is, of course, obvious that their use is by no means absolutely confined to such situations. Nor is it a matter of necessity that they should be small. Mr. Ramsbottom informs us that he has erected twenty-three of these engines during 1865 alone, in Bradford, Halifax, Leeds, Dewsbury, &c. &c., which are employed for various purposes, such as driving printing machines, circular saws, mortar mills, wool cranes, piece rolling mills, and so on. The engines are so constructed that they measure with great accuracy the quantity of water consumed per month or day, an important feature.

“In certain employments great variability of speed and frequent stoppages are required, and for such uses, as well as for other reasons, single cylinder water engines are not so well adapted for rotary motion. With double cylinders, however, duplicate valvular apparatus is required, and great care must be observed in duplicate valves to avoid counteraction, crossing, or opposition of the currents. Very great precision also is required in so erecting water engines, that the centres of both cylinders shall be central with the crank shaft, so that the arcs of oscillation

traversed shall be in proper relationship to each other to avoid the counteraction above mentioned. And all intermediate adjuncts betwixt the valves and their source of motion and the pistons and cranks, as connecting rods, &c., should be discarded, as the slackness of link-pins and the vibrations of these rods are most pernicious in machines which obviously can have no lead. Our engraving shows only one arrangement, but those engines are constructed variously, according to the uses for which they are required: in some cases horizontally, with a projecting crank shaft as shown, upon which the driving wheel or pulley is fixed; and in other cases, with a pair of single cranks on each end of the shaft and the driving gear betwixt them. The valves, instead of being flat as shown, are occasionally made with projecting cones, which form portions of the trunions or rocking centres; but, as in any form the practical value of these engines depends on the nature of the valve gear, it is to the construction and action of these portions of the engine that the makers have particularly directed their attention, rather than to the various forms of erection, which may be as various as those of the ordinary steam engine.

“Fig. 1 is a vertical elevation of the engine partly in section; fig. 2, a plan; fig. 3 shows section A B, through fig. 1; and fig. 4 shows section X Y, through fig. 3; fig. 5 is an elevation of cylinder, showing face and port ways; and fig. 6 is a similar elevation of the valve box; fig. 7, top view of the cylinder cover and gland. A, fig. 1, is the crank shaft, with double cranks at right angles to each other; *b*, are cylinders which oscillate by the crank motion on the rocking pins; C C¹ are setting-up and supporting screws, to adjust the necessary tightness of the cylinder faces against the valve faces D to any variable water pressure. Hardened steel discs are inserted betwixt these screws and the cylinders to receive their thrust; E are lock nuts to retain the pins in position when adjusted. The piston packings are ordinary inverted leather cups. G is the valve box, which is divided into two compartments by a vertical midfeather M, which separates the feed ports H from the exit ports K; see figs. 3 and 6. This valve box is duplicate, with faces on each side, the ports of which are in the same linear parallelism, and they are constructed to form exact segments of a circle, the centre of which is

the centre of the valve face, and the radius of which extends to the centre of the crank shaft. N are the port ways in the cylinder passages in fig. 1, and in the cylinder faces fig. 5, each of which port ways are caused, by oscillation, to become alternately feed and exit. As they vibrate across the midfeather the one port passes to the right side as the other passes to the left. And the breadth of the midfeather, or space betwixt the ports of the valve faces, and the breadth of the ports in the cylinder faces being similar, these latter ports are closed on the dead centres. For, in a water engine, the feed and exit ports should not only be open until the stroke of each piston terminates, but the capacities should increase and diminish in exact relationship to the relative velocities of the pistons. That is, when the motion of one piston is greatest at mid-stroke, its ports should be full, and should then die away as this piston approaches its termination, the opposite piston and ports being brought at the same time into full effect. If these conditions are not maintained there is valvular inaccuracy to be compensated for by the use of air vessels or other extraneous means to avoid counteraction and concussion. The apparatus for recording the amount of water used is the ordinary indicating gear in use for gas meters, attached to the engine in any convenient situation, and actuated either by the crank shaft or the oscillation of the cylinders; and as the stroke of the pistons is always equal in length, this length being determined by the cranks, the displacement per stroke is definite and uniform, and the engine being double-acting, the defects of tumbler valve motion are thereby obviated, and the measurement of water used is thus rendered more reliable than by other methods.

"We need only add that the entire apparatus is eminently portable. Being self-contained, it may be set down and put to work in a very few hours, while it is moderate in price and takes up little room."

57. *Novel Hydraulic Machine.*—From the "Mechanics' Magazine" we take the following paragraph:—"There was to be seen a short time ago, between the Pont Neuf and the Pont des Arts, a new hydraulic machine, invented by M. Roman, 37, Rue de Lille, Paris, for utilizing the force of currents and deriving a motive power therefrom. It consists of a large raft or barge similar

in size and shape to the open washhouses on many continental rivers. This is fitted with a series of transverse rollers, on which moves an endless chain passing under the boat, and fitted with a great number of float-boards, two metres asunder. A greater surface is thus brought to play against the current than in an undershot-wheel, which yields, even in the best condition, barely 30 per cent. of the theoretic force of the water. As in all ingenious and useful inventions, the principle on which this machine acts is of extreme simplicity and facility of application. If we suppose a float of an undershot-wheel submitted to the action of a current of water which impels it with a given force ; if to this float we add a second parallel to the first, at two metres distance behind it, the second float will also be impinged upon by the water. It has been clearly demonstrated by experiment that the effort exerted on the second float is equal to 75 per cent. of that brought to play upon the first. A third floatboard will be subject to the same laws as the second, the result being, that a series of parallel floats will obtain from the force of the stream a motive power only limited by the velocity of the water and the constructor's design. Last year, a small trial-machine, six of the boards being constantly immersed, gave by Prony's dynamometre, a useful effect of three, four, or even five times that of an ordinary undershot-wheel. The present machine has always thirty-four float-boards immersed ; and though the velocity of the Seine is only 45 to 48 centimètres (17·72 in. to 18·9 in.) per second, in the trials made in presence of a correspondent of the *Iron Trade Circular*, the useful effect has been on an average twelve times greater than that of ordinary wheels. As to the applications of this hydraulic engine they are innumerable. Geared into a series of pumps, either for the supply of towns or for purposes of irrigation, it is capable of becoming a great source of economic power ; while the working expenses are reduced to the charge of simple inspection, no manipulation being required."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION
FOURTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

Caloric Engine,—Scientific American, p. 318, vol. for 1866, Illustrated.
Ammoniacal Gas Power Engine,—English Mechanic, March 9, Illus.

Lenoir's Gas Engine,—Engineering, March 23, Illus.

Drake's Gas Engine,—Engineering, Feb. 23d, p. 123.

The Lenoir Gas Engine,—Engineer, May 18th, p. 387.

Sir W. G. Armstrong's Water Pressure Machinery,—Engineer, March 30th, p. 223, 249.

Turbines at the Philadelphia Water Works,—Engineering, April 27th, p. 269.

Machines for Raising Water,—Mech. Mag. Oct. 19th. p. 239, Illus.

DIVISION FIFTH.

TOOLS.

58. *The Workshop Tools of the Crewe Locomotive Works*.—The locomotive works at Crewe, belonging to the London and North Western Railway Company, have for some time been celebrated, not only for the able general management by which every department is distinguished under the care and superintendence of the manager, Mr. Ramsbottom, but for the remarkable ingenuity displayed in the designing, construction, and practical working of the various mechanical appliances, nearly all of which have emanated from the fertile brain of Mr. Ramsbottom. By far the best account given of these works and their appliances, so far as we have seen, has appeared in the "Engineer," and from a series of articles there given we take those portions referring to the *Workshop Tools* of the establishment.—"Amongst the heavier tools invented by Mr. Ramsbottom is an extremely original and important one for cutting out the sweeps of locomotive crank axles. Crank shafts above a certain size are usually forged with the crank in a solid block, so that the sweep has afterwards to be cut out of the solid. Many makers of portable engines still prefer to bend a shaft into the arms of the crank, giving as one reason that the fibre of the metal is not cut through in this case. Straps are sometimes shrunk on each arm of the crank of the locomotive shafts in order to make up for this supposed weakening; and, though many look upon this proceeding as unnecessary, it is known that a bar of wrought iron is often stronger longitudinally than transversely to its fibre. However this may be, it is certain that a locomotive double-crank shaft could not well be forged in any other way but with the cranks in solid blocks.

The usual mode of getting out the superfluous metal before setting the crank in the lathe is to fix it on the table of a slotting machine, and to cut two slots up to the required distance, either by means of one or of a pair of tools, the piece being thereupon broken out by driving in wedges. The intended neck is then of a square section, and it has afterwards to be pared down in the lathe. Last year, however, Mr. Ramsbottom invented and set to work a machine by which this process is done in a much more mechanical way and at a more rapid rate—the crank necks being so pared down to a circular section that no rough work is left for the turner. The annexed engravings (not given here) show this machine, but for the sake of space the main driving gear has been left out. The idea of the machine may be said to consist in using a large rose-cutter, set on a shaft parallel to the crank to be operated upon, the crank having a slow rotating motion against the rotating tool, the distance of which from the crank can be varied. On a lathe bed, provided at one end with an adjustable headstock, are cast, parallel with and at some distance from the fixed headstock, the bearings and framing for a massive rocking shaft. On the shaft is fixed the rotating cutter, which can thus, by means of the vibration of the shaft, be set to a greater or less distance from the crank being cut out. At the other end is a large worm-wheel, driven by a screw from the main driving gear. To this worm-wheel is bolted a speed pulley driving a similar one opposite. This pulley works a screw on its spindle, driving a small worm-wheel, which again, in its turn, by means of a screw, causes a large worm-wheel, keyed on the spindle of the fixed headstock, to rotate, and with it the crank fixed between the two centres. By means of a left and right-handed screw, what we have termed the rocking shaft can, with its rose-cutter, be adjusted to the required distance from the crank. In dealing with straight axles, much lathe work is saved by a tool, the production of Messrs. Greenwood and Batley, of Leeds, for cutting to one length a number of axles at the same time. We noticed eleven axles set on a fixed table, the ends of which were being cut by a number of tools fixed on a revolving face-plate with a traversing motion. It is well known that case-hardened articles swell up unequally after the operation. After being case-hardened the surfaces of the axle bearings are ground up by turning them

against a small stone, adjusted on a slide rest and caused to revolve at a high velocity. The heavy lathes here are pushed to work to their utmost limits of production, and in one case we witnessed not less than seven tools at work in turning down an axle.

“The useful machine patented in 1864 by Mr. F. W. Webb for shaping the insides of the rims of locomotive wheels is essentially a locomotive tool—though, at the same time, it is not improbable that it might be found useful in cleaning up other wrought iron work required to revolve at high velocities, and, therefore, needing to be perfectly balanced. The trouble and expense of chipping and filing the insides of wrought-iron wheels in order to clean them up is well shown, and the files used are also rapidly worn out on the skin of the iron. If, on the other hand, it be attempted to diminish the labour of the fitter, additional work is thrown on the smith. It is also now generally acknowledged that forgings worked close up to the intended finished dimensions are very liable to be ‘hammer-hardened’ by the cold-hammering, and thus rendered brittle. But even without regarding these important reasons, there is now a general tendency in the construction of workshop tools to diminish the expensive labour of the smith by leaving more stuff to be cut and pared off by the steam-driven tool. Amongst these machines is the wheel-rim shaping machine, of which we give an illustration; and we understand that it can clean out a wheel at one-twelfth the price previously paid for the same work by hand. At one end of the plain bed-plate is fixed the working part of the machine, the remainder of the length of bed being given to the table for carrying the wheel to be shaped. The vibrating lever for shaping the inside of the wheel is carried on a bracket, cast to the main plate of the fixed head. The cutter-holder end of the curved lever is formed with a bearing, in which is placed the cutter. It is secured by a set screw, and as it can, within a practical range, be set to a greater or less distance from the axis of the holder, the radius of the curve being cut, can be lengthened or shortened. The other end of the lever has a slotted arm, and a brass sliding block is fitted into this slot. The block is in an adjustable radius, being held in a slot in a disc keyed on the end of a shaft worked by gearing from another shaft, on which are

fixed the fast and loose pulleys from the driving belt. The wheel, while being cut, is held up by a pair of rollers, one on each side of the cutter, carried on a slide. The wheel itself is worked round by a feed motion, or on a table similar to that adopted for vertical slotting machines. By these means the inside of the rim is shaped out, but the curve at the junction of the spoke with the rim has necessarily to be cut in a different way. The revolving feed motion is then stopped, the tool itself being caused to describe an arc of a small radius. This is done by forming the upper part of the tool-holder as a short shaft, which passes through the end of the vibrating lever. By means of a worm wheel at its top end, worked by a worm fixed to a spindle, upon which can be fitted a handle, the attendant on the machine can cut out the curve before adjusting the machine for the next space between the spokes. Amongst the heavier tools are specimens of Messrs. Beyer and Peacock's large vertical drilling machine—a sample of which was to be seen in the western annexe of the 1862 Exhibition.

“A number of lighter machine tools, originated at Crewe, and probably to be seen at no other shop, are employed for a variety of work. A tool of great importance in a large locomotive workshop is the machine used here since 1861 for strengthening and centering the copper stay bolts for the locomotive fire-boxes. No insignificant amount of skilled labour is saved by it, and a gentle pressure is substituted for the blows which must often imperceptibly damage a copper stay. It is, indeed, not improbable that, when we consider the ductility of copper, these stays may be much improved by a compressive action. As will be remembered, the engraving we published last week shows three rollers, two of which are in the same vertical line, one above the other, while the third is adjustable, being movable on an eccentric spindle. The two fixed rollers are geared together by spur wheels as shown. The stay is dropped in between them, the adjustable roller being brought forwards by an oscillation of the handle, and the copper stay is then squeezed straight. Firmly held in this position, the adjustable square centre is simultaneously brought up against one end of the stay, and as the other is encountering the fixed square centre, it is also centred at both ends. By reversing the action of the machine, the stay drops

out, and can be at once fixed in the chasing lathe. Embodying a distant resemblance in principle to this tool is the valuable ferule finishing machine designed in 1863 by Mr. Webb, the out-door manager. The general arrangement will be at once understood when we observe that the ferule is shaped between three rolls whose ends are free and projecting from the frame of the machine. They are arranged in a triangle, the two fixed ones below, and the adjustable roller above. Pressure is put on this roller by means of a lever, and it is thus intelligible that, when the ferule is slipped on the top roller, it is rapidly and easily shaped between the three. Another of the many machines introduced by Mr. Ramsbottom is the slide-bar grinding machine, introduced as long ago as 1854. It is a very wasteful process to set a good fitter, paid at the rate of some thirty shillings per week, to alternately 'draw-file' such work and to keep his file free from 'pins.' Instead of this they have used at Crewe for several years a machine in which the bars are fixed in a trough, while over their top surface a brass polishing wheel, fed with fine emery and oil, is made to traverse. A tool saving much chipping and filing is the drifting machine, designed in 1861 by Mr. Ramsbottom, for squaring the bolt-holes in such details as cylinder covers and the flanges of glands or pipes. It consists of a simple arrangement for forcing a long taper drift, made with a number of teeth arranged, so to speak, in steps. The working part is about 14 in. long, the teeth being pitched $\frac{3}{8}$ in. apart; and its circular end is of the same diameter as the circular hole which is to be squared out. This tool is fixed to a ram working vertically in a long socket bolted to an upright girder, to which is also fixed the table carrying the work.

"A great number of smaller machines are placed on a storey above one of the tool shops. The lightness and simplicity of the work, obtained by means of the automatic machinery, allow a good number of young boys to be here employed, so that this shop is facetiously termed the 'nursery.' We noticed here a simple contrivance by the aid of which washers could be turned bright in the lathe in an incredibly short time. In this simple operation much time is lost by the apprentices usually put to this work, through the more or less frequent application of the callipers, sometimes accompanied with the operation of stopping

the lathe. All this is avoided by setting against the washer, at the reverse side to that cut by the tool, a little gauge hanging loosely in a hinge. Before turning up a number of washers, this gauge is adjusted in a standard which is fixed till all are done. When a rough washer is fixed in the lathe, the little gauge is leaning against it, forming an angle with the horizon, which gradually diminishes as the stuff gets turned off. As soon as the last cut is taken the gauge instantly drops down, warning the boy that the required diameter is reached, and the job done. The numerous name-plates required are done in a way which must save many a pound to the fortunate shareholders. To those cognisant to the well-known principle of Blanchard's copying lathe the mode adopted will be at once clear. Two similar name-plates are cut out at one time at a boring machine furnished with two spindles. The table is movable, being adjusted to the necessary curves and letters by means of a template, the counterpart of the name-plates being drilled, or rather slot-drilled, out. The machine is worked by a machine labourer, and it turns out in one day an amount of work it would take ten skilled engravers to do within the same time. In turning up nuts much of the time is taken up in stopping and starting the lathe at the times when the work is being removed. This is saved in a lathe fitted with a simple contrivance by which a clutch is made to slide up and grasp hold of the exterior of the nut. Being turned round at a quicker speed than the work, the nut is rapidly removed when finished. This plan has more than tripled the daily production of the lathe. The elegant curve of a properly shaped snap-head bolt, so much prized by the lovers of good workmanship, is sometimes miserably mauled by a careless or incompetent turner; and, in any case, much time is lost in trying on the gauge. Mr. Ramsbottom while going through the works some time ago, had his love of proportion offended by some badly-shaped snap-heads. He accordingly schemed the contrivance shown in Figs. 1, 2, and 3, (not given here), which has been found to turn out excellent work with great rapidity. As is seen, a cylindrical tool is adjusted into the socket of a rod able to turn in all directions in a common ball-and-socket joint; against the handle is fixed a template made of the magnified shape it is wished to turn out or copy on the head of the bolt-tools. It is evident that,

notwithstanding its great simplicity, the contrivance also possesses general adaptability; though, as a rule, one qualification has often, in tool-work, to be sacrificed for the other.

“In another part of the works we witnessed some wall-drills, arranged in a simple, almost rough way, but in such wise that the work could be very quickly set. The table was shifted in a parallel line to the wall, on a pair of rails, one being a V-rail. The wood-working shops are provided with a very complete assortment of the most modern wood-working machinery, amongst which we witnessed a machine on the slot-drilling principle for mortising work. The hammer handles for the smiths and other artisans are turned out in a Blanchard lathe, and smoothed up by a plan we have not seen anywhere else. It is an importation for wood-work of the familiar emery-wheel of the fitting-shop. Next to the cast-iron rim of the wheel is a layer of soft ‘sponge-cloth,’ then comes one of brown paper, and over all one of canvas. On this is glued glass-dust, forming a polishing surface on which the handles, as they come from the Blanchard, are rapidly smoothed for use. This glaze lasts one week’s work.

“We now come to another class of tools, specially designed by Mr. Ramsbottom for doing the several precise jobs required to be executed in locomotive repairing work. Their special character consists in their portability, whereby they can be set to work without taking too many details to pieces. The steam-port facing machine, which we illustrated recently, forms an excellent example of the combination of judgment and invention characterising Mr. Ramsbottom’s designs. It has been working since 1853. Its great simplicity scarcely makes a description necessary; and it will at once be seen that the scraping tools are in one piece with a disc, each bolted to a worm-wheel driven by the large central screw. This screw acts on both wheels at the same time, thus covering the valve face vertically, while the self-acting feed-motion carries the cutters onwards. The whole combination forms a remarkable instance of the adaptation of the screw and worm-wheel. A machine for dressing up the horn-blocks is on the same principle, and it is made sufficiently long to take both the opposite blocks at the same time. As showing what can be done with these machines, it may be mentioned that one fitter and a labourer can face up a valve face in one day’s work. The

motive power is supplied by a cotton cord driven from the line of shafting passing through the centre of the shop. The shafting pulley used is in halves, so that it can be fixed anywhere without adjusting the engine. The pulley driven by the cord is shown on the plan view of the engraving of the valve-facing machine. The cylinder-boring machine for re-boring the cylinders is driven in the same way. It is constructed on the usual plan of a boring head fed along a boring bar by a worm-wheel motion.

"One of Kendall and Gent's well-known little machines is used for cutting the brass tubes to the requisite length. It has been reported that the hydraulic test is not used by Mr. Ramsbottom for boilers; but the contrary is the truth, and even all the brass and copper tubes are tested up to 200 lb. The hydraulic test is now used for both the old and new boilers. The rings of the barrels were formerly gauged, both before and after the application of the pressure, by means of thin iron hoops. This plan has, however, been discontinued. The old tubes are cleaned by mutual attrition. They are simply placed in a long cylinder punched with holes; on being caused to revolve, the friction thus induced is found to rid them completely of any scale on their outsides. A very simple and efficient contrivance of Mr. Ramsbottom's for cutting off the ends of the brass tubes in their places is shown in the engraving, Fig. 4, (not given here). The cylindrical end, made to the inside diameter of the tube, is inserted up to the depth determined by the stopper shown to be fixed to this rod by means of a pair of screws. A small steel cutter is fitted into a tapered dovetail made in a bent bar kept up by a powerful spring, and the whole apparatus is caused to revolve by the handle at the back; the tube is cut through a plane exactly at right angles to the inside diameter of the tube, the internal surface of which, in fact, serves as the guide for the operation." The drawings referred to in these notes, and those of other machines not here alluded to, will be found in current numbers of the "Engineer" for 1866,—amongst others in numbers for Feb. 9th, Feb. 16th, and March 5th.

59. *Adamson's Drilling Machine (a). Collier's Boring Machine (b).*—For the following paragraphs on these machines we are indebted to "Engineering." The drawing referred to in (b) will be found under date ("Engineering") of May 4th, 1866.—(a) *Adam-*

son's Drilling Machine. "In the course of an article on the joints of locomotive boilers, in our last number, we alluded to the practice followed by Messrs. Adamson and Co., of Hyde, of drilling the rivet holes in the boilers constructed by them after the plates had been put together. About four years ago Mr. Adamson, in conjunction with Mr. Levi Leigh, patented a peculiar arrangement of drilling-machine specially adapted for drilling the holes in the transverse joints of boilers, and in this machine he has since introduced improvements which have also been patented by him. The improved machine consists of a large circular bedplate, above which, supported by four columns, is placed an upper plate carrying the driving gear of the machine. A hollow central column is fixed to the lower bedplate, and around this column are placed two tubes, the outer one having cast upon its lower end a circular table furnished with radial arms upon which the rings of boiler plates which are to be drilled rest. The tube just mentioned has also a table formed upon its upper end, and between this table and a plate placed above is held a ring which is connected, by arms passing through slots in the column, with the nut of a screw, which passes down the centre of the column, and is furnished with a bevel-wheel at its lower end. This bevel-wheel is connected by means of a horizontal shaft and bevel gear, with a hand-wheel at the side of the machine, and by this arrangement the tube on which the table supporting the boiler-plates is formed can be adjusted vertically to any desired height. The plate which we have mentioned as being placed above the top table of the tube is provided with radial arms which bear against the inside of the boiler-plates just above the joint being drilled, and prevent them from being pushed out of place by the pressure on the drills. Between the central column and the tube carrying the tables is another tube, to the lower end of which a worm-wheel is keyed. The worm gearing into this wheel is fixed upon the same horizontal shaft as a dividing wheel placed at the side of the machine, and by turning this wheel, therefore, the tube, and with it the outer tube and the arms supporting the boiler-plates, can be turned round through any desired distance.

"We must now describe the drilling arrangement. In the bedplate of the machine are formed a series of radial grooves

(twelve being found to be a convenient number), which serve as guides for a corresponding number of short columns, each similar to that of the slide rest of a wheel lathe, disposed around the plates being drilled. Each of these columns has fitted to the top of it a slide carrying a horizontal drill spindle, the drill being directed radially against the joint of the boiler-plates. The slides at the tops of the columns give the power of feeding each drill forward to its work, whilst the radial grooves in the bedplates enable the columns to be set at various distances from the centre, to suit different-sized boilers.

"We have said that the machine has an upper frame supported at a considerable height above the bedplate by four columns: this bedplate carries a number of radial countershafts placed one directly over each drill-spindle. On each countershaft is a strap pulley, from which a strap is led to another pulley fixed upon the corresponding drill-spindle; the pulleys on the countershaft slide on feathers in the shafts, so that they can be adjusted radially to the various positions of the columns supporting the drill-spindles. Besides the countershafts, the upper frame of the machine also carries at its centre a short vertical shaft furnished with a bevel-wheel at its upper and another at its lower end. The lower bevel-wheel gears into bevel-pinions placed one at the inner end of each radial countershaft, whilst the upper bevel-wheel is driven by a bevel-pinion keyed upon a horizontal shaft, which also carries the speed pulleys for regulating the speed at which the drills are worked.

"In using this machine the rings of plates to be drilled are placed upon the supporting arms, and are adjusted vertically, by means of the screw within the central column, until the centre of the joint, formed by the junction of the rings, is in a line with the drill-spindle. As many holes as there are drills can then be drilled through it simultaneously, and after this has been done and the drills withdrawn, the rings can be turned round for a distance equal to the pitch of the rivet holes, and the operation repeated. By thus drilling the holes through both the plates of a boiler joint after they have been put together, all drilling and riming is of course rendered unnecessary, and a much better class of work can be turned out than when the old system of punching the plates separately is followed."

(b) *Collier's Boring Machine*.—"The great increase which has, during the last few years, taken place in the size of our marine engines and other machinery has rendered necessary the employment of tools of a far heavier description than those formerly used. Of such tools we have already given several excellent examples in the present volume, and to these we now add a large vertical drilling and boring machine, constructed by Messrs. William Collier and Co., of Salford. The engravings of this machine, on page 286, which have been prepared from a drawing kindly furnished by Mr. James Fletcher, represent a front and side elevation of it, and clearly show its general arrangement. The bed of the machine is 18 ft. in length, and is furnished with V grooves similar to those of a planing-machine, upon which slide three tables for carrying the work to be drilled or bored. The central table is 6 ft. long, and each of the others is 2 ft. long; they can all be shifted along the bed by means of a rack and pinion movement. The central table has a slot in it, 2 ft. long, through which the boring-bar can pass.

"At one end the bed is increased in width, and upon the part so widened are erected a pair of strong standards which support, by means of a cross frame, the boring machinery. The shape of the standards will be seen from the side elevation. The main spindle is of wrought iron, and is 9 in. in diameter: it is carried by two bearings, one level with the under side, and the other with the upper side of the cross frame, which is deepened in the centre. The boring-bar inserted in the socket at the lower end of the spindle, passes down through the central table, and is steadied by running in a bush placed in a strong stay attached to the bed. The spindle is driven by a bevel-wheel fixed upon it just above the lower bearing, this wheel being geared into by a pinion keyed upon a horizontal shaft placed as shown in the engravings. The shaft just mentioned carries a set of cone pulleys; and it, and a countershaft placed above it, are furnished with gearing similar to that fitted to the headstock of a lathe, so that the machine can be run either in single or double gear as may be desired. The machine is driven by a 6 in. belt. The cross frame, with the whole of the boring apparatus, can be raised or lowered, it being secured to the side standards by bolts passing through slots in the standards, as shown in the figures.

"The spindle has a vertical traverse of 8 ft., the feed movement being effected as follows: The apex of the spindle is provided with a crosshead, the arms of which carry a pair of nuts working on a couple of screws placed one on each side of the spindle above the cross frame. One of these screws is right and the other left-handed, and the nuts are coupled so as to work together by means of spur-wheels formed on them, as shown in the engravings. The nuts are driven by a pinion which gears into one of them, and which is carried by a vertical shaft passing down on one side of the screws. At the lower end of this shaft is a spur-wheel, into which a pinion, fixed upon another vertical shaft, gears; this last shaft is driven from the main spindle by spur-gearing and a friction-box, the latter giving the power of varying the amount of feed. For raising the spindle quickly, the shaft just mentioned is furnished with a bevel-wheel, driven by a bevel-pinion fixed upon a horizontal shaft carrying a pair of fast and loose belt-pulleys. By using this arrangement, which is shown in the front elevation, the spindle can be readily raised when the machine is at rest; the feed gear being of course disconnected. The total weight of the machine which we have described, and which appears very simply and effectively arranged, is nearly 40 tons. One of them has been supplied to the Dennystown Forge Co., of Dumbarton, by Messrs. Collier, who had previously made a similar machine of slightly less dimensions."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION FIFTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

- Angus's Cylinder Boring Machinery*,—Engineering, Nov. 9th, p. 345, Illus.
German Water Jet Pump,—Engineering, Feb. 23d, p. 117, Illus.
Lock's Rock-boring Machinery,—Engineering, Feb. 23d, p. 120, Illus.
Kirk's Refrigerating Machine,—Engineering, Feb. 23d, p. 124, Illus.
Davy's Steam Hammer,—Engineering, Feb. 2d, p. 68, Illus.
Fenby's Permutating Key-cutting Machine,—Engineer, Oct 5th, p. 251, Illus.
Seller's Planing Machines,—Engineering, June 22d, p. 418, Illus.
Pumping Machinery at the Stadil Fjord,—Engineering, Jany. 5th, p. 13, Illus.
Merrilees and Tait's Sugar Mill,—Engineering, July 20th, p. 44, Illus.
Carrett's Coal-cutting Machine,—Engineer, Aug. 31st, p. 150, Illus.
Nelson Brothers' Boring Machine,—Engineering, Aug. 3d, p. 74, Illus.
Ramsbottom's Tire-making Machinery,—Engineer, June 29th, p. 468, Illus.

- Hooker's Pump*,—Scientific American, p. 214, vol. for 1866.
- Richard Roberts' Multifarious Punching Machine*,—Engineering, Oct. 19th, p. 303, Illus.
- Poncelet's Water-Wheel at Bascot Park*,—Engineer, Aug. 3d, p. 82, Illus.
- Masting Shears at the L. and N. W. Railway Landing Pier, Holyhead*,—Engineer, Aug. 3d, p. 78, Illus.
- Winby's Hydraulic Rolling Mill*,—Engineering, Nov. 2d, p. 342, Illus.
- Ore Stamping and Crushing Machines*,—Engineer, Aug. 10th, p. 100, Illus.
- Robinson's Nail Cutting Machine*,—Engineer, Aug. 17th, p. 114, Illus.
- Bank-Note Printing Machine at the Bank of Ireland*,—Mech. Mag., March 30th, p. 200, Illus.
- Spoke Turning Lathe*,—Mech. Mag., Sept. 28th, p. 197, Illus.
- Flanging, Bending, and Welding Machines*,—Mech. Mag., Oct. 26th, p. 260, Illus.
- Screw Peg Making Machine*,—Mech. Mag., Nov. 2d, p. 277, Illus.
- Rivet Trimming Apparatus*,—Mech. Mag., June 1st, p. 344, Illus.
- Cork Cutting Machine*,—Mech. Mag., April 6th, p. 216, Illus.
- Scroll Cutting Machine*,— „ „ „ 13th, p. 233, „
- Steam Hammers*,— „ „ „ „ 232, „
- Hoblyn's Lathe Rest*,— „ „ May 18th, p. 313, „
- Stamping and Crushing Machine*,—Mech. Mag., June 15th, p. 374, Illus.
- Steam Pumping Engines*,—Mech. Mag., June 15th, p. 376, Illus.
- Cutting, Punching, and Bending Machinery*,—Mech. Mag., June 15th, p. 377, Illus.
- Precipitating and Dressing Machinery at the Devon Great Consols Mine*,—Engineer, May 25th, p. 377, Illus.
- Todd's Duplex Planing Machine*,—Engineer, June 8th, p. 414, Illus.
- Whitworth's Duplex Lathe*,—English Mechanic, April 20th, p. 71, Illus.
- Gray's Portable Steam Rivetter*,—Engineer, Feb. 23d, p. 144, Illus.
- The Lathe and its Uses*,—a series of articles in the English Mechanic, commencing July 6th, p. 300, and in following Nos., July 13th, 20th, and 27th, Aug. 3d, 10th, 17th, 24th, 31st, Sept. 7th, 14th, 21st, 28th, Oct. 5th, 12th, Nov. 2d, 9th, up to No. for Dec. 28th.
- Shanks and Kohn's Hydraulic Forging Press*,—Engineering, June 8th, p. 380, Illus.
- Hydraulic Tip Dutch Rhenish Railway*,—Engineer, Feb. 16th, Illus.
- Dead-stroke Pavier Hammer*,—Scientific American, p. 134, vol. for 1866.
- Cotton Press for India Missions*,—Engineer, April 13th, Illus.
- Ridley's Concrete Mixer*,—Engineer, May 18th, Illus.
- Webb's Curvilinear Shaping Machine*,—Engineer, Feb. 9th, Illus.
- Ramsbottom's Tube Cutter, and Machine for getting up Snap-bolt-heads*,—Engineer, Feb. 10th, Illus.
- Centrifugal Fans*,—Engineer, Feb. 9th.
- Samson and Cox's Shaping Machine*,—Engineer, Feb. 9th, Illus.
- Planing Machines*,—Pract. Mech. Journal, Nov., Illus.
- Overhead Travelling Cranes*, by Moore, Liverpool,—Pract. Mech. Journal, Nov., Illus.
- Nelson's Radial Steam Hammer*,—Engineering, May 18th, Illus.
- Steam Travellers, Blackfriars Bridge Works*,—Engineer, June 15th, Illus.
- Thwaite's and Carbatt's Steam Hammer*,—Engineering, March 16th, Illus.
- Hydraulic Pressing Apparatus*,—Practical Mech. Jour., June.
- Tangyes Multiple Screw Cutting Lathe*,—Prac. Mech. Jour., May, Illus.

- Bolt-heating Machine*,—*Prac. Mech. Jour.*, April, Illus.
Davis's Steam Striker,—*Engineering*, April 13th, Illus.
Kennard's Duplex Rivetting Machine,—*Engineering*, July 20th.
Curvilinear Slotting Machines,—*Engineering*, Jan. 26th.
Grey and Burton's Travelling Cranes,—*Mech. Mag.* Aug. 17th, Illus.
Bolt-screwing and Nut-turning Machinery, *Sharp, Stewart, & Co.*,—*Engineering*, Sept. 21st, Illus.
American Cupola Blowing Machine,—*Engineering*, Jan. 19th, Illus.
Pile Cutting Machinery,—*Engineer*, May 11th, Illus.
Hydraulic Slotting Machine,—*Engineering*, June 29th, Illus.
Shears for Plate Iron,—*Mech. Mag.* Jan. 26th, Illus.
Ramsbottom's Machine for Straightening and Centering the Copper Stays of Locomotive Boilers,—*Engineer*, Feb. 2d, Illus.
Ferrule Rolling Machine,—*Engineer*, March 9th, Illus.
Plate Bending Machine,—*Engineering*, May 14th, Illus.
Cylinder Facing Machinery,—*Engineering*, Nov. 2d, Illus.
Machine for Testing Strength of Iron (Tanjye's),—*Engineering*, Nov. 2d, Illus.
Rotatory Steam Hammer,—*Prac. Mech. Jour.*, Jan., Illus.
Kirkaldy's Testing Machinery,—*Mech. Mag.*, March 9th, Illus.
Portable Boring Machine,—*Scientific American*, p. 398, vol. for 1866.
Law's Air Compressor,—*Engineering*, April 20th, Illus.
Ericsson's Compressors for guns,—*Engineering*, May 18th.
Nut-shaping Machine, *Sharp, Stewart, & Co.*,—*Engineering*, Sept. 14th, Illus.
Centrifugal Fans and Pumps,—*Engineer*, April 20th, Illus.
Joy's Steam Hammer,—*Engineering*, May 25th, Illus.
Retort Charging Machinery at the Chartered Gas Works,—*Engineering*, Sep. 21st, Illus.
Wheel-cutting Machine,—*Engineering*, Oct. 5th, Illus.
Rolling Mills,—*Engineer*, Jan. 12th.
Steel Tyre Rolling Machinery,—*Engineering*, Sep. 28th, Illus.
Machinery for Rolling and Straightening Metallic Rods,—*Mech. Mag.*, Nov. 16th, p. 309.
Portable Steam Rivetting Machines,—*Engineer*, Feb. 9th.
Grimshaw's High-speed Compressed-air Hammer,—*Newton's London Journal of Arts*, Jan. 1st.

DIVISION SIXTH.

MECHANICAL APPLIANCES.

60. *To Keep a Circular Saw in Order*.—The following is from the "*Scientific American*:"—"Much has been said already on the above subject. But a plain man, unacquainted with technical phrases, would find much to puzzle him, and I think if he

followed all the directions given, his saw would puzzle him still more. For the benefit of such men, using mills in hard timber, please give me a little space for a few practical rules.

First, To work well the saw must be perfectly round, set the guide up until it touches the shortest tooth. File all the rest until they will pass, and it is round.

Second—Have the under edge of the tooth to range with a circle, three-fifths the diameter of the saw; the top or back of tooth one inch from the point, nearly one-eighth lower than the point. This is of vital importance.

Third—Spread the points of teeth with the upset, exactly alike on both sides, using a gauge; but do not bend the teeth. Upset enough to make the saw clear perfectly.

Fourth—File the teeth perfectly square, and the same length on both sides. The top near the point about one-sixteenth of an inch in length chisel-shape. This strengthens the point of tooth. One upsetting filed that way will last two days.

Fifth—Set the saw mandrel, so that the saw, having run a straight line, will just show daylight between the saw at the centre and the log.

Having got this right, never move it under any circumstances.

Sixth—Do not run your saw at the circumference two miles a minute, as advised by Mr. Emerson. If you do, you won't get back the same day; 450 revolutions for a 60-inch saw is fast enough.

Seventh—File the under edge of your teeth once every 1,000 feet of lumber cut. A smart hand will do this in five minutes. It is the most profitable five minutes of the hour.

Eighth—When the lead gets wrong, stop and file your saw. Tinkering will not make a dull or a badly filed saw run well, and you cannot very easily make a well-filed saw run bad.

These rules, strictly followed, will enable any man, who can use a file, to run a mill with fair success whether his mill has end motion or not. If you undertake to saw 16,000 feet without filing the saw, do not blame end motion, or any thing else but your want of judgment if you have trouble. If a dull saw will cut 16,000 feet in a given time, the same amount or more can be made by keeping the teeth sharp, and made much easier.

What would you think of a man who would mow six hours without whetting his scythe. It can be done. But how much easier and better if he keeps his scythe sharp.

The Martin and Ashcroft attachment is an excellent thing for the purpose for which it is designed, but do not substitute it for filing and setting the saw. Mr. Ritchie's advice is good when he says, 'when your saw commences to vary, correct it at once.' But it is bad when he says 'change the lead of your saw.' The proof of this follows in Mr. Ritchie's own statements that 'he finds it necessary to change the lead many times a day.' In morals, it is said one bad step leads to many more. The above confession proves that one bad move by a sawyer (moving the saw mandrel) leads to a like result in a mechanical point of view.

Ten years' experience with circular saw mills, both with and without lateral motion, leads me to the conclusions indicated. I put up one of the first circular mills used in Ohio—a Lee and Leavitt, with lateral motion. I have used three of their mills, one of Lane and Bodley's, no end motion, and one Blandy. They will all make good lumber if the saw is kept in proper order. If the saw is not filed and set right, neither of them or any other mill will work well. A. S. PETTIGREW."

61. *Pins and Eyes*.—We take the following useful article from "Engineering," of July 6th, 1866:—"A pin, passing through eyes formed on those parts of a machine or structure which are to be joined together, is a form of connexion of most frequent occurrence, both in civil and mechanical engineering. For instance, the links of the chains of suspension bridges are so connected, and so are the diagonals and flanges of Warren girders, whilst in machinery it forms the usual form of connexion between the parts of all link work. In all these cases, but more particularly in bridge work, it is important that the size of the pins and eyes should be so proportioned to the strain upon them, that they be of equal strength with the parts which they connect. In machinery, where the parts are subjected to motion, sufficient bearing surface has to be provided to prevent heating, and it is generally this consideration which governs the size of the parts—those proportions which give the requisite bearing surface being generally amply sufficient as far as mere strength goes.

“In those cases, also, where there is little or no motion between the parts to be joined, the question of bearing surface has more to do with the proportioning of the sizes of the pins and eyes than is commonly supposed. In such connexions, the parts are almost always arranged so that the pins are subjected to ‘double shear,’ or, in other words, they must, before they fail, be broken through in two places. Under these circumstances, the area sheared through is of course equal to twice the sectional area of the pin, and in the case of wrought-iron pins and links subjected to tensile strain, it would at first appear therefore that the sectional area of the former should be equal to half that of the latter, the resistances of wrought-iron to shearing and tension being about equal. For instance, if we had two links each with a sectional area of 12 square inches at its smallest part, and the end of one of them was made with a double eye embracing the end of the other, then, if the resistance to shearing only had to be considered, the connecting pin might have an area of 6 square inches. Whether this area would or would not be sufficient, however, would depend to a great extent upon the form of the eyes at the ends of the links. In the first place, the jaws of the double eye must be prevented from opening, and so throwing a bending instead of a shearing strain upon the pin; and, in the second place, the thickness of the eyes must be such that they have sufficient bearing upon the pin, and so do not fail from distortion. The opening of the double eye is generally prevented by means of a head on one end, and a nut, or collar secured by a pin, on the other end of the pin; but the second requirement, that of bearing surface, is very frequently neglected. In cases where, as in the links of a suspension-bridge chain, the thickness of the links is very small in comparison with their width, the bearing surface which the pins would have, if made with the proportions above mentioned, would be quite insufficient, and the consequence would be that the holes would be distorted, and the eyes torn.

“When the late firm of Fox, Henderson, and Co. were constructing the chains of Mr. Vignoles’s suspension-bridge over the Dnieper at Kieff, a number of interesting experiments were tried to determine the proper proportions for the eyes of the links and the connecting pins, and the results obtained were given in a

paper afterwards read by Sir Charles Fox before the Royal Society. As the chains for this bridge weighed over 1600 tons, and had to be carried from Odessa to Kieff, over 300 miles of very bad roads, it was of great importance that all useless weight should be avoided, and consequently that no superfluous metal should be employed in their construction. For convenience of transit, the links were made 12 ft. long from centre to centre of pinholes, and $10\frac{1}{4}$ in. by 1 in. throughout the part between the eyes. The eyes or heads were also 1 in. thick by $16\frac{1}{2}$ in. in diameter, and were at first pierced with holes $4\frac{1}{2}$ in. in diameter for the reception of the pins, which latter had thus an area of 15.9 square inches, or rather more than half as great again as the smallest sectional area of the links. Notwithstanding this excess in the sectional area of the pins, however, they were, upon experiment, found to be quite unable to develop the full strength of the chains. The links were made from iron manufactured by Messrs. Thorneycroft and Co., from a mixture of Indian and other pig iron, and had a tensile strength of about 27 tons per square inch, and each link ought, therefore, to have borne, if the pins and eyes had been properly proportioned, a strain of at least 270 tons. Upon the test being applied to one of the links, however, it was found that it failed under a strain of 180 tons, the head or eye tearing across at its widest part, where the sectional area was 12 square inches.

“This result led to the supposition that the eyes were too small, and some experimental links were accordingly made with eyes $18\frac{1}{2}$ in. in diameter. These, however, were found to fail in a similar manner, the pin-holes in both this and the former instance being drawn into a pear-shaped form, and the metal being bulged on that side which had received the strain. Under these circumstances it was determined to increase the size of the pins, thus giving greater bearing surface, and diminishing the intensity of the strain upon the eyes. One of the links, with a $16\frac{1}{2}$ in. head, was accordingly taken, and the pin-holes enlarged to 6 in. in diameter, so that each pin had a semicylindrical bearing surface of 9.4 square inches instead of 7 square inches, as in the former experiment; and the result of this alteration was, that the breaking strain was augmented from 180 tons to 240 tons, notwithstanding that the head had less metal in it than before.

Further experiments, subsequently made, indicated that the diameter of the pins might have been still more increased with advantage, the best proportions appearing to be those which gave each pin an area of semicylindrical bearing surface about equal to the least sectional area of the links. Sir Charles Fox considers that it is best to make the bearing surface slightly in excess of the proportion just mentioned, and he thus gets, for the pins of suspension-chains, the simple rule that the diameter should equal two-thirds the width of the body of the links.

“As the sectional areas of the pins increase as the squares of their diameters, whereas the bearing surfaces increase only as the diameters directly, it follows that whilst, in the case of small sizes, a pin of the requisite sectional area may give an excess of bearing surface, so, on the other hand, a large pin having the requisite bearing surface will have an excess of sectional area. In cases where the pins are exposed to ‘single shear,’ the change from the one condition to the other will take place, with links 1 in. thick, at that size of pin, which has a semicircumference in inches equal to its sectional area in square inches, or at a diameter of 2 in. ; with thicker links this diameter will be less, and with thinner, greater. In pins of large size, when, in order to obtain the requisite bearing surface, the diameter is made much larger than would be necessary to give the proper sectional area, the dead weight may be diminished by making them hollow, care being of course taken that the thickness of such tubular pins is sufficiently great to prevent any distortion taking place when strain is applied to them.

“In determining the proportions of the eyes through which the pins are passed, it must be remembered that the strain upon the metal composing them is not uniformly distributed, the stress being more severe upon the inner parts than upon the outer. To compensate for this, Professor Rankine advises that the sum of the sectional areas of the two sides of an eye should be made one-half greater than would be required if the strain was uniform. The experiments on the links for the Dnieper bridge, above mentioned, show, however, that a less proportion than this is sufficient. The links tested had, when fitted with the 6 in. pins, but $5\frac{1}{4}$ in. of metal on each side of the pin-hole, whilst the body of the link was $10\frac{1}{4}$ in. broad ; and, under these circumstances,

the breaking strain was 240 tons against about 270 tons, which, according to the trials of the iron, would have been required to break the link through the body. From these results Sir Charles Fox estimates that the sum of the widths of the two sides of the eyes should be about 10 per cent. greater than the width of the body of the links, this rule, of course, referring to those cases in which the link and eye are of uniform thickness throughout.

“When circumstances will allow of its being done, the best way to obtain the requisite bearing surface for the pins connecting links of small thickness in proportion to their section, is to increase the thickness of the eyes beyond that of the links themselves. This allows the metal around the eye to be made narrower, and it thus consequently diminishes the inequality of the strain throughout its section. Where the links to be connected are of square section, or are of considerable thickness in proportion to their sectional area, this thickening of the eyes becomes unnecessary, as sufficient bearing surface is given without it. A rule, for the size of eyes, which has been much used, and which gives generally very good results, is to make the outside diameter of the eye equal to twice the diameter of the pin passed through it, and then to increase the thickness until the requisite sectional area is obtained.”

62. *Relating to Gears.*—“Every wheel that comes from the foundry has a vitreous scale on it, caused by the partial fusion of the sand and facings, which makes it wear well and run easy, and it seems the acme of folly to remove this and expose the softer part below to the abrasion experienced at work.

“What is it that makes wheels rattle and jar at work when all the details are firm and solid? And what is it that springs shafting, breaks hangers, forces them out of line, and keeps bearings chronically hot so that all the oil which can be poured on is of no avail? It is teeth grinding one on the other; it is wheels with teeth out of time; it is wheels with teeth of fancy shapes, ill-proportioned and entirely defective as regards their essential points. There is but one correct shape for a tooth. Man may scheme and plan as he will, to one shape it comes at the last. Nothing within the whole range of mechanical movements is more beautiful and simple than the transmission of power from one wheel to another by two projections rolling on each other—

rolling but never rubbing; each point passing the other with no more than rolling friction, which is the least of all resistances.

“That wheels shall so act, depends entirely on the shape of their teeth, supposing, for brevity, that all other mechanical parts are right. If we make teeth pyramidal in form, as they are made in one of the largest and oldest machine shops in this city, they grind and rub for years until they have worn a path for themselves that they can follow with ease. Then tooth and space are alike out of proportion, and with any change of velocity, backlash ensues; one lags until the other catches up to it, and rattle, bang and clash is the order of the day. If we make teeth semicircular at the top and semicircular at the bottom of the space, we take away part of the impelling surface in order to make the wheels mesh properly, and we load the apex or crown of the tooth with a portion of metal which exerts no useful effect but entails waste of material and of power.

“The proper form of a tooth is the epicycloidal, or that curve which is generated by one circle rolling on another circle. As this curve is never constant, but changes with every diameter and pitch, all the circumstances or conditions must be taken into account before wheels which will work mathematically correct can be made.

“If this well-known fact was rigidly followed out, however, the greatest confusion would ensue, and for every wheel needed, a different set of cutters would have to be made. This would not only be costly but wholly impracticable in the ordinary business of the workshop. A manufacturer who wanted a gear cut without delay, would hardly be disposed to wait until the foreman could go to his factory, look at the size of the driver, count the teeth, make templets and then cutters before his order could be filled. The variation in the shape of a curve, therefore, is so small that it need not be considered in practice, and for wheels of all sizes, such as change wheels for screw cutting engine lathes, a few cutters will answer, commencing, we will say, at those for 50 teeth and running both ways to 12, which is about the lowest gear.

“A common way of finding the shape of teeth is to strike the curve from the pitch circle of the next tooth. Not the centre of

the tooth, *but its side*. This and a subsequent process gives a curve approximating to an epicycloid; not a true one by any means, but a simple and ready way of forming a tooth that will run and wear well, and a method that is within the reach of every one. The curve so struck from the pitch line outward to the crown of the tooth gives the working side, while lines drawn from the pitch line to the centre, give the base of the tooth. The result of these will give an angle more or less acute at the pitch line, governed by the size of the wheel, which is of course to be rounded off.

"The only correct way to lay off the teeth is on the pitch line, not on the chord of the pitch line. The way to arrive at this is to step off, by an infinite number of small spaces, the pitch on the arc, and then to take the chords found as a constant by which all the other distances may be obtained. It is usual for the pitches of pinions of small diameter, working in large wheels, to be a little greater than the wheels they drive or are driven by.

"A true epicycloidal curve may be formed by making segments of wood of the size of the intended wheel, and gluing thin slips on the back of them; something like the flanges which are often made on pinions. The curve of the wooden segment represents the pitch line of the wheel, while the thinner slip projecting beyond it represents the crown of the tooth or outside diameter. Two small steel wires—stout needles will answer—must be pushed through the slips, so that the points come out exactly at the pitch line and at the crown. By placing these segments together and rolling them over each other, as the wheels act when at work, true epicycloids will be formed on the inside of the slips, from which patterns can be taken to shape the teeth by. The points must not project too far through the wood, or they will stick in and not mark. It will be found that the shape thus given is acute at the point of the tooth—too much so for common use, and it must therefore be cut off, but nothing must be added to or taken from the working curve.

"It is not at all difficult to make a set of wheels revolve one another. If we take a blank, put it in a milling machine on an arbor, set the index, and start the cutters, a wheel will be produced that will mesh when two are put together, but something more than meshing is needed, and when the teeth are not cor-

rectly laid off—or rather shaped—one face will slide on the other face instead of rolling over it.

“Beside the shape of the teeth there are other points essential to be considered. These are the width and depth in proportion to the pitch.

“The best English practice makes the width of the tooth of spur gears for ordinary work, or where the velocity does not exceed five feet per second—an axial width equal to four times the thickness, and five times the thickness where the velocity exceeds five feet per second. The length is given at five-eighths of the pitch and never to exceed three-fourths of the same. Outside of the pitch line the length is four-twelfths, below it five-twelfths; which, in the neat length of the whole, from bottom of space to crown of tooth, equals three-fourths of the pitch.

“In an absurd hand-book recently published we are told that the pitch line is the centre of the tooth. This work purports also to give directions how to make and cut gears. No set of gears can run properly in that way. The working diameters are at the pitch lines, and the centre of motion is also there in properly made wheels; but if the middle of the tooth is the pitch line, the gears will bottom when at work, or else the pitches cannot coincide. This is the way tons of gearing are made in this country, and it is needless to tell men of common sense that it is wrong. Wheels must have good clearance at the bottom, and have their pitch lines coincident at all times to obtain the best result.

“Quantities of cast gears are used on reapers and mowing machines, but they run badly. Sometimes inaccuracies occur through shrinkage, and in others, patterns which were once perfect are destroyed by time and ill-usage so that they are no longer reliable. All such should be looked after, condemned, if beyond repair, and new sets made on proper principles.

“No set of cast gears can run quietly and perform well otherwise, where they are bored out untrue; where they are keyed on so as to be set to one side, even if they are true, or where they are oval through imperfect shrinkage, as before remarked. There is a draft side on every pattern, and cast gears should be meshed so that the draft sides are opposite each other, but in more than one instance we have seen men carefully filing the teeth down

'because they were thicker on one side than the other,' thereby wasting time and spoiling files.

"This article has been drawn out much beyond our average allowance of space, because we have felt the importance of it. Much more might be said with profit, and attention to the principles alluded to will result in a great change for the better in gearing."—*Scientific American*.

63. *On Frictional Screw Motions and Applications*.—From a paper read before the Society of Engineers in Scotland by Mr. James Robertson, we take the following introductory portion,—the remainder of the paper will be found, with accompanying illustrations, in the number of the "Civil Engineer and Architect's Journal" for February, 1866:—"The object of this paper is to describe a system of frictional screw motions, with which the writer has been more or less engaged for the last ten years, and which appears to be a principle of mechanical action not previously recognised by mechanics, and one of very considerable importance. The application of the principle seems also infinite, and can produce useful effects where the common groove-threaded screw is unserviceable; but is one requiring mechanical nicety and tact to apply it rightly, and, moreover, brings with it so much change in the form of the machines to which it can be applied, that it is at considerable expense and risk, in most cases, that it can be usefully developed.

"The writer, though familiar with many useful applications of this principle, having been otherwise closely engaged, has therefore, not sought to apply it to any purpose involving much risk in the form of expense, nor allowed it to occupy his time in any considerable degree, except for such purposes as have happened to come in the wants of his own engineering practice. It is hoped, however, that by some information given on the subject, and a more general recognition of the principle by engineers, useful applications will increase more rapidly, as there are many of these motions suited to particular branches of machine manufacture; and many men, with many mechanical ends to reach, would find use for this principle were it well understood. Any contrivance of a generic or organic nature that forms a useful and obedient organism to the designer of machines for producing the motions and effects he desires in the shortest way, and with the

least expenditure of force—contrivances such as the cog-wheel, the thread-screw, the crank, eccentric pulley, &c.—is of greater importance than the combination of these, and adaptation of them in a machine for any particular purpose, as new motions tend to suggest new adaptations in machines, and these motions, after a little study, will not merely be found useful for some purposes already accomplished, but also suggest new operations not hitherto attempted. They will not supersede the ordinary thread or groove screw to any considerable extent; but are suitable for many purposes, and for producing effects of a nature which it would be impossible to accomplish with the common screw.

“Frictional screwing action is produced by any body that causes continuous oblique tangential impingement on a revolving cylinder or round bar, where the cylinder or bar is free to move on *end* as well as to revolve. The force at which it will revolve and screw forward on end is proportional to the frictional contact of the impinging body, and the pitch of thread described or produced proportional to the angle formed by the direction of motion of the impinging body to the axis of the screw-bar or cylinder. In some of the larger applications made, the force of the screwing action, though not accurately measured in any case, would range from 10 to 20 tons, and the thread or pitch of screw described perfectly accurate or uniform throughout, there being no limit to the force that may be exerted, or difficulty of producing perfect uniformity of pitch by these screw motions, although the purposes to which they are likely to be applied with most advantage are not those that require either great power or minute accuracy of action.

“The mechanical properties possessed by these screw motions, as distinguished from the ordinary screw, are chiefly the properties of indefinite variation, or change of thread, or pitch of screw, producible in one screw, any pitch being readily obtained from an infinitesimally small pitch, to direct rectilineal motion on end; and of reversing the thread from right to left without changing the direction of the motion of the nut or screw; the mechanism which constitutes the nut being in most cases easily adapted to do this.

“The mechanism which constitutes the nut is very varied—screwing action being effectively generated, or produced by

straight or curved bars, by parallel or by bevelled pulleys, or a combination of these acting tangentially on the surface of a round bar or cylinder, and these, instead of surrounding the screw like an ordinary nut, acting external to, and revolving on different axes to the screw bar, giving thereby a great variety of new facilities of application, as both nut and screw, while they are acting in this relation to each other, may be serving other purposes in the machine, and their functions as a screw motion of a secondary character.

"The primary principle of these motions will be understood by Fig. 1, Plate 8, (see number of the "Civil Engineer and Architect's Journal" for Feb. 1866), consisting of a cylinder mounted on an axis, and placed on bearings so as to be free to move on end, and to revolve freely, representing thereby the screw, and having placed in effective driving contact with it a parallel frictional pulley of sufficient breadth to withstand wear, keyed on an axis, and held in bearings in a forked holder having a lever fixed in the fork so as the axis of the frictional driving pulley is kept horizontal to the plane of the screw barrel, but may have its axis set by the lever, shown at right angles, or at any intermediate angle with the axis of the screw barrel, thereby representing the nut. Motion being communicated to this pulley by the belt pulley and strap shown, and communicating motion by its contact with the frictional screw, causes it to revolve; and, on the lever and axis nut pulley being held at an angle to the axis of the screw barrel, a screwing action at a corresponding angle, as indicated by the dotted helix line on drawing, is produced; and when the screw pulley is turned round to a corresponding angle in the opposite direction, a reverse or left-hand screw motion will be described as indicated by the left-hand screw dotted helix line in barrel; and any intermediate screwing motion, in either direction, can be described without changing the direction of the motion of the nut or screw, from a screw of an infinitesimally small pitch of thread up to direct rectilinear motion on ends.

"Figs. 2 and 3 are elevations of similar screw motions; Fig. 3 showing a nut composed of two frictional pulleys, placed at opposite sides of the screw barrel, in which position the contact pressure on the axis of the barrel is neutralized, and double the effective contact thereby obtained.

“By increasing the number of nut pulleys, the adhesion between the nut and screw may be increased to any required degree, without causing too great a pressure on the axis of the nut pulleys, although, for most purposes, two pulleys are sufficient and most convenient. Motions of this nature, chiefly of an experimental character, as adaptations for feed traversing motions, for tools, &c., have been tried, but it would be tedious to enter into the details and modifications of these, the figures having been given chiefly to illustrate the principle of these motions.”

64. *Cork Springs*.—“In a recent report upon new mechanical applications the secretary of the Franklin Institute called attention to the use of cork in place of india-rubber as a support for freight cars and like heavy vehicles. One would not be led by any means to predict the efficiency of cork in this connection from ordinary impressions of its properties. The cork used for these springs is of the commonest description, harsh, hard, and full of fissures. It is cut into discs of about eight inches diameter, each pierced with a central hole. Previous, however, to cutting it it is soaked in a mixture of molasses and water, which gives it some softness and renders it permanently moist. A number of these cork discs are placed in a cylindrical cast iron box, a flat iron lid or disc is placed over them, and by hydraulic pressure is forced down so as to reduce the thickness to one-half. A bolt is then run through box, corks, and cover at the centre, and a nut being screwed on this holds all in place, when the press is relieved, and the box of compressed cork, disc, or cork spring is ready for use. One of these springs, placed in a testing machine under a weight of 20,000 lb., shows an elasticity suggestive of compressed air in a condensing pump. One would expect from the appearance of the material, that under heavy pressure it would be pulverised or split into shreds, especially if this pressure was assisted by violent shocks; but, in fact no such action takes place. A pressure which destroys india-rubber, causing it to split up and lose its elasticity, leaves the cork unimpaired, and, with the machinery in use, it has even been impossible, with any pressure attainable, to injure the cork, even when areas of but one inch were acted upon. In connexion with this subject the president, Mr. William Sellers, remarked, at the conclusion of the secretary's report, that he had for some

five years employed a forging machine in which a spring of the form and material above described was used and subjected to continual and violent shocks, and that its performance had been most thoroughly satisfactory, with no signs of deterioration.”—*English Mechanic*.

65. *India-Rubber Springs*.—We take the following article from “Engineering,” on the above subject:—“A block of india-rubber when subjected to compression yields in two ways; first, by an actual compression of the material itself, and second, by an alteration of its form, or bulging. When india-rubber is required to act as a spring this alteration of form should as far as possible be avoided, either by disposing it in thin laminæ with intermediate division plates, or, if a thick block is used, by supporting it with retaining rings placed around it. If a cylinder of india-rubber be placed under a load sufficient to crush it, it will bulge, and a ring of a triangular section will be broken out all around the central part of it; and if this ring be removed and the load then taken off, the cylinder will be found to have assumed a form somewhat resembling that of an hour-glass. It was from a knowledge of this fact that Mr. G. Spencer determined upon the shape of the india-rubber cones, now manufactured under his patent and largely used for buffer and draw-springs, these cones assuming under pressure an almost cylindrical form and filling the malleable cast-iron cups in which they are contained.

“The elasticity of india-rubber under a compressive strain decreases as that strain is increased, equal increments of load not producing equal deflections: thus a column of india-rubber laminæ which yields $\frac{1}{2}$ in. under a load of 1 ton will not be compressed 1 in. by a load of 2 tons, but considerably less, and so on. The elasticity of an india-rubber spring composed of laminæ separated by division plates, varies not only according to the total height of the elastic column, but also according to the thickness of the layers of which it is composed. For example, a spring consisting of a given number of laminæ of a given thickness will yield, under a certain load, only about half as much as a spring composed of half the number of laminæ each of double the thickness; although the height of the elastic column will be the same in the two cases.

“The fact of an india-rubber spring giving a gradually increas-

ing resistance to compression, renders it badly adapted for use as a bearing spring on rolling stock, as it is impossible, unless an exceedingly high elastic column be employed, to obtain a spring having sufficient elasticity to follow up closely all the inequalities of the road. For buffing and draw-springs, however, this qualification renders the material peculiarly applicable, and it has long been in use for such purposes with excellent results. It has also done good service when arranged as an auxiliary in connexion with the ordinary steel bearing springs, according to the system patented by Mr. P. R. Hodge. It is employed in this manner on the Great Eastern, the North London, and several other lines, the india-rubber springs being composed of a series of laminæ $\frac{3}{8}$ in. or $\frac{1}{2}$ in. thick, separated by division plates, and interposed between the ends of the steel springs and the engine frame. The india-rubber springs are found to effect an important saving in the breakage of the steel springs, to which they are applied; they should not be loaded with more than about 3 cwt. per square inch of surface, indeed it is better that the load should not exceed 2 cwt. per square inch, and they should be carefully protected from oil.

“The duration of an india-rubber spring of course depends greatly upon the quality of the material of which it is composed. Pure india-rubber is of little or no use; it is necessary that it should be ‘vulcanized,’ as it is called, by treatment with sulphur, and that it should be mixed with a certain quantity of other substances. Some of the best india-rubber for railway purposes contains as much as 40 per cent. of foreign matters, chiefly sulphide of lead and soapstone. Bad india-rubber is frequently adulterated with plumbago. The only true test of the fitness of any particular description of india-rubber for any given work, is to subject a sample of it to such work for a considerable period, and notice the result; it being most difficult, even for those who have had considerable experience, to obtain, from an inspection or analysis of the india-rubber itself, more than a general idea of the manner in which it will perform.”

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION SIXTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

- Traversing Screw Jack*,—Engineering, Nov. 9th, p. 357, Illustrated.
Vice Combination-pipe,—Prac. Mech. Jour., p. 375, No. for March.
Leather Washer Cutter,—Prac. Mech. Jour., March.
Raising and Lowering Apparatus Tangyes,—Prac. Mech. Jour. for Aug.
Tweddel's Tube Fixer,—Engineering, May 11th, p. 313, Illus.
Waterhouse's Shaft Coupling,—Scientific American, p. 214, vol. for 1866.
Gould's Twist Forge,—Scientific American, p. 102, vol. for 1866.
New Centre for Lathe,—English Mechanic, Jan. 12th, p. 198, Illus.
Registering Micrometer Callipers,—Scientific American, p. 118, vol. for 1866.
Tube Expander for Locomotive Boilers,—Scientific American, p. 70, vol. for 1866.
Boring Collar and Drill Chuck,—English Mechanic, Jan. 19th, Illus.
Rea's Lubricator,—Mech. Mag., Sept. 28th, p. 197, Illus.
Theory of the Driving Belt, by E. Sang, F.R.S.E.,—Prac. Mech. Jour., Oct. and Nov., Illus.
Shaft Coupling,—Mech. Mag., June 27th, Illus.
Hydraulic Pivot,—American Artisan.
Stocks and Dies,—Mech. Mag., May 11th.
Hydraulic Boiler Tube Fixer,—Mech. Mag., June 22d, Illus.
Hoblyn's Compound Slide Rest,—English Mech., October 12th, Illus.
Drilling Tube Plates,—Engineering, Jan. 12th, Illus.
Brook's Lubricator,—Engineering, Jan. 26th, Illus.
The Atmospheric Insulator,—English Mech., Feb. 16th, Illus.
Machine Manipulation,—A series of papers in the English Mechanic, commenced June 1st.
Basson Lubricator,—Mech. Mag., Aug. 31st, Illus.
Transmission of Power by Belts,—Scientific American, p. 51, Illus.
Principle of the Hydraulic Ram,—Mech. Mag., Oct. 26th, p. 257.
Water as a Lubricator,—English Mech. and Mirror of Science, March 2d, p. 336, Illus.
Proportions of Cast-Iron Pipes,—Engineering, Jan. 19th, p. 47.

DIVISION SEVENTH.

METALS.

66. *On the Management of Steel*.—From the "Mechanics' Magazine," we take the following practically useful article:—"Iron is more valuable than gold. There is no metal fitted for so infinite a variety of purposes, or which enters so largely into familiar and every day use. Iron ore is the commonest mineral

we have, being found in apparently inexhaustible stores in nearly every part of the earth. In our own country, it is hardly necessary to remark, it exists in the utmost abundance, and in conjunction with coal, which, happily, occurs in its close proximity, and, hitherto at least, has been equally plentiful, has mainly contributed to make England the great and wealthy power which she is. But for these two substances, and the unrivalled facilities which they have afforded her for the manufacture of iron and steel, more particularly since the application of steam power, England's progress, and the world's, must have been slow indeed. It was remarked years ago, by a writer, 'The gold, the silver, the precious stones—these are the objects in general of human cupidity; yet, all the wealth, not only of "Ormus and of Ind," but of Australia and California to boot, might be exhausted to-morrow without involving a loss that would be half so deplorable as that of the coalfields of Great Britain alone.' The description is not less true as regards our ironfields, and it is to be hoped that the present fears of scientific men in England as to the prospective exhaustion of our coal may not be so well founded as is supposed, since the manufacturing industry of the country so intimately depends upon the union of our coal and iron. The man who contributes to our knowledge of this metal, to which we owe so much, who can tell us something useful regarding its manufacturing capabilities for important purposes, performs no small service. Mr. George Ede, of the Royal Gun Factories Department, at Woolwich Arsenal, is entitled to the credit of having done so. His work on 'The Management of Steel' has reached a fourth edition—a proof that it has at least found readers. Without any great literary merit, which we scarcely looked for, the book is valuable for its thoroughly practical character, and the knowledge of the subject which it evinces. Especially will young mechanics find it useful in their profession. The author gives his experience of the various processes known in the manufacture of iron, and its conversion into steel. Beginning with the iron ore he describes it briefly under the two first states in which it is employed for mechanical purposes—that of cast iron and wrought iron. Coming to steel—the last state of iron manufacture—we get the well-known inventions of Mr. Benjamin Huntsman, of Sheffield, and Mr. Bessemer explained, and then follow chapters upon the

choosing of steel for tools; the forging of iron and steel, the annealing, hardening, and tempering of cast iron and steel; the case-hardening of wrought-iron; and the toughening of steel for guns, shot, and railway bars. Under each of these heads Mr. Ede says a great deal in a few words. As it is of the utmost importance to young mechanics to be able to know a good tool from a bad one, that is to say, good from bad steel, we think we cannot do better than give them the benefit of the author's experience, and the results of his observations upon this point. In the first place it is difficult to tell the quality of steel by sight; it is a test uncertain at best. Nor is the method of breaking a bar to observe its fracture, and select that which has a moderately fine grain, to be depended upon, since a variation in the fracture will be caused by the hardness or softness of the steel, and it is well known that some steel of very indifferent quality, breaks very close in the grain. To really ascertain the fitness of steel for tools which require a fine firm edge, the best way is to forge some of the steel. If the steel be good and suitable for this purpose, it will not bear a white heat without falling to pieces, at a bright red heat it will crumble under the hammer, while at a middling heat it may be drawn under the hammer to a point as fine as a needle. Whether at a high or low heat, inferior steel will not take such a fine point without splitting, and consequently will not receive a fine firm edge. Though it is a simple process—the drawing of a piece of steel to the testing point—it is, nevertheless, one that requires some attention. If you take a piece of steel cut from a bar, and proceed to draw the extreme end of it to a point, and the end of the steel should happen to be in the least concave previous to hammering it, you will find it impossible to get a fine sound point, although the steel may be the best Sheffield. So long as a concavity exists in the steel it will not take a fine sound point, and hammering will only increase the concavity. However, this may be avoided by first filing to a rounded point resembling a centre punch, but not quite so sharp, the extreme end of the piece of steel under trial, and if the steel be tenacious it will draw to the required point. To test the hardening properties of steel let the piece be drawn out again under a low heat to a gradually tapered square point, but not so fine as before,

then plunged at this heat into pure cold water. If the point, having been broken off just enough to show the fracture, will easily scratch glass, the steel has good hardening properties. Mr. Ede prefers this mode of testing to the common way of applying a smooth file, arguing that as files differ in hardness, of course they can indicate only imperfectly the hardness of the steel. The next operation is to find out the degree of the steel's tenacity. This is done by placing the broken piece of steel upon a piece of hard cast iron, and crushing it under the face of a small hardened hammer. If the steel be good it will not only resist the crushing, but will bury itself in the cast iron, cutting the hammer's face in the process. Inferior steel, on the other hand, having no tenacity, will not stand this test. It will be either crushed flat or ground to powder. The excellence of steel will always be in proportion to the degree of its tenacity in its hard state. In its soft state, a curved line fracture and uniform grey texture as a rule denotes good steel. The appearance of threads, cracks, or sparkling particles is a proof of the contrary. Among other tests mentioned by the author are the following:—'Good tool steel in its hard state on fracture presents a dull silvery appearance, is more close in its texture than annealed steel, and is of a uniformly white colour, with the entire absence of sparkling particles. If aquafortis be applied to the surface of steel previously brightened, it will immediately produce a black spot; but if applied to iron the metal remains clean, so that it will be quite easy to select such pieces of iron or steel which possess the greatest degree of uniformity, as the smallest vein, either of iron or steel, upon the surface will be distinguished by its peculiar sign.' We may add that Mr. Ede's little work, which we heartily recommend, is published by Mr. Tweedie, of the Strand."

67. *Steel in Construction, (a) and (b)—Steel in Compression, (c)—Steel in Ship Building, (d).*—The enormous development which the manufacture of steel in large masses has received through the agency of the Bessemer processes, has attracted the attention of engineers to its use for various constructive purposes, as bridge-making, ship-building, and the like. Not much is known with certainty as to its properties and powers of resistance when used on the large scale, but every day is adding to our experience in connection with it; and some of our ablest men are institut-

ing, or are about to institute, experiments upon it, which will be of immense service to the profession. The following suggestive papers we borrow from the pages of the "Engineering," (a) being from the paper of date, Feb. 16, 1866; (b) March 2d; (c) March 9; and (d) March 30th, 1866.—(a) *Steel in Construction*.—"It is comparatively but a few years since bridges were constructed only in stone, brick, or timber, because none knew how to plan them in other materials. Afterwards we had cast-iron, and with its almost infinite facility of form, the opportunities for original design were greatly multiplied; especially after the late Mr. Eaton Hodgkinson had shown us how properly to employ it, both in tension and in compression. For iron suspension bridges, dating from 1823 only, wrought-iron was employed as a matter of course. Twenty years ago there arose the necessity for wide strong spans, for the passage of railway trains, and between Mr. Stephenson and Mr. Fairbairn two of the grandest bridges known to modern times were successfully constructed of a material which until then had been thought wholly unfit for the purpose. More recently, the production of steel has been assimilated in cheapness and in the weight of single pieces, to the manufacture of wrought-iron. The tensile strength of what is known as mild steel, or homogeneous metal, and which is identical, when made, with much of the Bessemer steel, is at least twice that of wrought-iron. The so-called homogeneous metal (made by an expensive process, as compared with that followed in making Bessemer steel) has been adopted for the chains or inclined tension bars of the new Albert-bridge, from Chelsea to Battersea-park, and there can be little doubt that it is altogether superior to wrought-iron. But here the metal is employed in tension alone. In bridge structures of different design, as in arches and girders, the metal is employed also in compression. Mr. Scott Russell, in a letter in our last number, has very forcibly directed attention to the necessity for further knowledge of the compressive strength of steel. At present we know very little upon this point. Steel has been for some years spoken of and written of as a material for future constructions, but the complete knowledge of its qualities which engineers should possess is yet wanting. If, as there appears reason at present for believing, steel has but little if any greater power of resistance to compression than wrought-iron, one half

of its presumed advantages for girder construction, and probably also for shipbuilding, have no real existence. Supposing, as Mr. Scott Russell has suggested, that steel can bear perhaps 40 tons per square inch in tension, but only 20 tons in compression, a steel girder would require to have a top flange of at least twice the sectional area of the bottom flange. Indeed the top flange might as well be made of wrought-iron as of steel, and the latter be employed only in tension. There may be, indeed, an advantage in this application of steel to the construction of girders. But it is most desirable that engineers possess more complete knowledge of the whole nature of steel for the purposes of construction, and it would probably be to the interest of the steel-makers if they would themselves take up the task of demonstrating its capabilities under different circumstances of service. Steel is now made at a price approaching nearly to that of wrought-iron, and there is a corresponding temptation to employ it, if it be found trustworthy. We have been informed that the homogeneous metal tension bars of the Albert-bridge cost but £25 per ton, and we are aware that Bessemer bar steel has been quoted as low as £16, and we believe it can be produced at a considerably lower price. It is now easy to conduct experiments upon every kind of material, so as to show all its properties, and such experiments should be at once made upon steel. It is of course probable that, as in the case of the Britannia-bridge, a series of experiments upon steel tubes, plates, and girders, may be found desirable in the interest of a railway company undertaking some one of the great bridges now commenced or contemplated. The question at present now remains in a most unsettled state, and whoever brings to bear the results of careful and appropriate experiments, applicable to all the circumstances under which steel is likely to be employed, will not merely render a timely and important service to the profession and to science, but will probably reap many direct advantages in his own practice."

(b) *Steel in Construction.*—"If it were known that steel possessed decided advantages over wrought-iron in the construction of ships and girders, engineers would be disposed to adopt it extensively, considering the low price at which it is now produced. It appears singular indeed that no one has yet found it to his interest to make the experiments necessary to establish the value

of steel for purposes of construction. At present we know next to nothing of the resistance of steel plates to compression, nor much of their extensibility under strain, or what is now termed the dynamic value of the material. Until these points are ascertained, either by engineers or by the steel makers (and the latter might, perhaps, take the initiative in the matter), we cannot expect to see steel employed in important works where it is subjected to compression. There is a general fear of steel for such purposes as yet, and there is, too, an impression that it has been tried, and that it has failed. But upon this point we have no evidence to offer. Engineers really know so little of what steel will bear when worked into the top member of a girder, and their impressions are so much against its fitness in such a position, that they can hardly bring themselves even to recommend their clients to incur the cost of experiments to set the matter at rest. Individually, engineers cannot afford the time, not to say the considerable pecuniary outlay requisite for proper experiments, having only a general applicability to future practice. We certainly think that the steel makers might well move in the matter. We know what trade jealousies are, but there ought to be firms quite above them. We should, indeed, suggest, supposing them to have confidence themselves in steel as a material for engineering constructions generally, that a number of firms supply, each, samples of what they believe to be their best qualities, and to instruct some disinterested mechanical engineer to work them up into girders, tubes, &c., and to engage some leading member of the profession to report upon the tests to which these might then be subjected. When the War Office desired to experiment upon cast-iron for ordnance, nearly a thousand samples were forthcoming from almost all parts of the kingdom, the makers being willing to take whatever position, as manufacturers, the results might indicate. It will be remembered how the West Hallam Ironworks obtained the best, and the Heyford Ironworks the worst position. Our own impression is that if the steel makers cared to submit their manufactures to experiment, they would, as a body, most benefit themselves by agreeing that the report upon the results should not specify whose make of steel was found to be best. Let it be tried as steel simply against iron, with the object only of making out a case in favour of the former. Divided among a

few firms, the expenses would not be large to each, and if the results were favourable, all might expect to share in an increased trade. We do not say that we have any great amount of confidence in the readiness of the steel makers to unite in this way, and we can anticipate almost the very terms in which more than one would ridicule it. But we should still maintain that if the steel makers as a body *would* unite to establish a position for steel in the eyes of engineers, a great increase in the steel trade would undoubtedly accrue. We thus suggest only a tradesman's motive, but they might find others worthier, if they desired to render a service to science. The great steel makers are, speaking pecuniarily, able to accomplish almost anything, and a few thousands of pounds are as nothing to them. It may be, indeed, that they are well satisfied with the steel trade as it is, and do not care for any immediate increase. But whether this be so or not, and while we admit that those in the trade are in no way bound to move in the direction we have suggested, we may as well state that it is seriously doubted in the profession whether steel, when substituted exclusively for wrought-iron, has any special advantages sufficient to compensate for its increased price.

“Mr. Kirkaldy has an admirable machine for testing materials up to great strains, and we have no doubt that many of the experiments required might be performed upon it. But at the same time other and more important trials require to be made upon steel worked up into structures. Sooner or later these will be made, and steel will take its position according to the results.”

(c) *Steel in Compression*.—“An interesting trial took place on Wednesday at Mr. Kirkaldy's experimenting works, to ascertain the resistance to compression of tubes and struts of Messrs. Shortridge, Howell, and Co.'s homogeneous metal. The tube tried was about 4 ft. long, its external diameter was $1\frac{7}{8}$ in., and its thickness $\frac{3}{8}$ in., giving a bore of $1\frac{1}{8}$ in. The cross sectional area was almost exactly $1\frac{3}{4}$ square inch. The ends of the tube were cut smooth, and at right angles to its axis, so as to give a fair bearing. A strain of 67,300 lb. was applied, equal to more than 17 tons 3 cwt. per square inch, when a slight lateral deflection was observed. The weights were then set to give a strain of 82,000 lb., equal to nearly 21 tons per square inch, but while the press was being pumped up to this pressure the tube flew out,

having yielded laterally. No crack or flaw was produced, however, in its substance, and the tube was afterwards bent double, in the cold state, without any visible injury of the material.

“Another experiment was made upon a strut formed of four ‘angle irons’ (if this term be not a bull in speaking of steel), rivetted up to a cruciform section. The angle irons were each $3\frac{1}{2}$ in. by $3\frac{1}{2}$ in. by about $\frac{5}{16}$ in., and were riveted by double rows of rivets in each leaf. The total cross section was 8 square inches and the length of the strut 4 ft. 370,000 lb. were applied in compression when the strut was shortened 0.31 in., and on removing the pressure it was permanently shortened 0.15 in. On increasing the strain to 385,000 lb., corresponding to nearly $21\frac{1}{2}$ tons per square inch, the heavy crosshead of Mr. Kirkaldy’s machine broke, and a thick circular plate of steel upon which the strut abutted was cracked nearly in two. Up to this point the steel strut showed very great strength, and it was but little injured by the strain under which the machine gave way. Mr. Kirkaldy will soon have his machine repaired, when further and more conclusive trials will be carried out.”

(d) *Steel for Shipbuilding.*—“On the occasion of the discussion of Mr. Rochussen’s paper, at the Institution of Naval Architects, on Thursday week, Mr. Reed said he should like to mention one or two of the causes which prevented steel being very extensively adopted at the present moment. He wished that Mr. Samuda had been present, inasmuch as that gentleman had recently taken a public part in urging the construction of a certain class of vessels, one of the main features of which was that they were to be made throughout, or nearly throughout, of steel—at least 80 or 90 per cent. of the ship was to be formed of steel. He (Mr. Reed) had taken great pains to ascertain the real nature of steel, and of that particular kind of steel which was recommended for ship-construction, and he had found some very singular facts. He was very much struck with the remarks of the reader of the paper as to the desirability of selecting steel with a view to the purpose for which it was to be used and the duty which it had to perform. In connexion with the steel which he was about to mention they had taken every precaution to describe the kind of service they wanted it for, and he believed that the makers of the steel were quite satisfied that what they supplied was the

right kind of material. When testing the steel they found that, although when it was broken through the solid plate it gave an extremely satisfactory strength and possessing a tensile strain varying up to 40 tons, yet over and over again the steel broke away from the rivet hole, and, taking it in that way, the breaking strain was reduced to 22 tons to the inch, so that in putting steel into a structure like a ship, which was subject to all kinds of strains, instead of there being an enormous increase of percentage of strength, there was actually an enormous decrease. The steel tried was of a superior quality, and they had not found in it that amount of uniformity which was generally supposed to exist in steel. They had tested puddled steel, crucible steel, and Bessemer steel, but had not yet obtained results which would at all justify them in a wholesale use of steel in the construction of ships. In order to test the matter as fairly as possible they had the rivet holes both drilled and punched, and they obtained a much more satisfactory result when the holes were drilled than they did when they were punched. Another objection to the indiscriminate and too hasty use of steel was that they had to ascertain, not merely the tensile strain, but also the compressive force of the metal. No doubt tensile strength was a very important matter, but when they considered that the bulkheads and sides of a ship were subjected to all kinds of compressive force, it became exceedingly important that the structure should be one able to bear that compressive force. He hoped it would not be understood that he considered the experiments which had been made as final; but he was sure that every gentleman present would agree that, until they had obtained more satisfactory results it would not be a judicious thing to build ships largely of that material. He thought it would be exceedingly unfortunate if a vessel built as Mr. Samuda suggested, with a turret and armour, should be made of steel. When they considered the number of openings in such a ship, it became a most momentous question whether the material of which the ship was built was likely or not to prove treacherous. He stated these views without the slightest attempt to discourage the use of steel beyond what was fair and just. He had gone over the works in Prussia, alluded to by the paper, and certainly nothing could be more admirable than the pains which were taken to produce an excellent material.

He only wished to lay before the institution the grounds on which they had gone warily to work in the adoption of steel, and to justify what some people had regarded as an indisposition to make progress.

“Mr. Grantham said he would offer no opinion at all as to the desirability of building steel vessels, but would give some of his own experience with regard to steel. About four years ago he was requested to construct a vessel for service in the river Trent, in a part where the river diminished very rapidly. The owners possessed four or five other vessels, but they wanted one of less draught, and he told them that the only resort, under the circumstances, was to venture upon a steel vessel. He had no experience at that time of such ships, but he designed a long fine vessel, and Messrs. Penn and Son made the engines. She drew about a foot less water than the former vessels, and answered the purpose remarkably well. He watched the vessel closely during her construction, and was informed by the builder—and his own observation confirmed the fact—that in no single case was a rivet hole cracked, nor did any of the rivets when bent show any sign of cracking. They were most ductile, and the men spoke of the steel in the most favourable way. Shortly after that he was applied to for a screw vessel, and though the party had several iron vessels, they determined, after what he had told them, to try a steel ship. He made them a steel ship which went to sea, and was at sea at the present time, and had encountered all the bad weather of this year. She was now three years old. When she was about one year old he heard that she was filled with water in the harbour in which she was accustomed to lie. He immediately apprehended that some treacherous place had been found in her which had cracked and let the water in. Upon inquiry, however, he found that the parties who built the berth in which she was lying had carelessly let some stones from the pier fall down into the berth, upon which she had sat down, and, as might be supposed, the consequence was that a hole had been made in her bottom. This was soon repaired, and the foreman afterwards told him that he had never in his life seen iron drawn so much under the circumstances before it broke, and that there were several indents caused by the stones which could not have existed in an iron vessel without fracture. He also

gave a most favourable account of the ductile state of the vessel. Shortly afterwards the parties who had the first ship wanted another, and so well satisfied were they that they had it made of steel, and, as far as his own observation had gone, he had no doubt at all that they had made a judicious choice.

“Mr. Reed asked if the rivets were tested properly.

“Mr. Grantham replied that they were, though he did not see them, but there was no evidence whatever of their having broken in the way Mr. Reed had described. The first vessels of which he had spoken were built of puddle steel, in contradistinction to Bessemer steel. This was all the experience which he had had in the matter, excepting that he had seen a great many works where steel was made. He gave no recommendation on the subject, but thought it was well that facts like those he had mentioned should be recorded.

“Mr. Reed, in answer to a question, stated that they most certainly did find that when steel did break through the rivet holes, it was at a much less tensile strain; and knowing this, they could not have much confidence in it.

“Mr. Scott Russell was one of those who had the greatest hopes of steel, but who had been brought, by burning his fingers, to use some caution in the application of it to ships. They could get steel of a quality which would stand a tensile strain on the square inch of 100 tons, but that would be a steel possessing no other good qualities than extreme hardness and extreme tensile strength. He was led, when he was a great deal younger than now, to buy one or two vessels with steel plates. From what he was told, he believed that when he had got plates that would stand 40 tons to the inch, he had only to build a steel boat half the thickness of an iron one, and that it would be as strong. He tested the steel, perhaps they would say, in an unfair manner, but it was a manner which suited his peculiar purpose. He wanted a very small boat, with a very small draught of water, with very great power; but he wanted to have all that power at the aft end, and of course he had to load her in the fore part, so as to get an even keel, and the effect was, that the vessel gave way entirely by breaking down. Under ordinary circumstances, however, he thought there was no fear for a steel boat, but he would ask steel manufacturers to give their greatest attention

to the amount of crippling strain which steel would bear, and then no one would more heartily encourage the building of steel ships upon a large scale than he should, because he believed that steel was to be the iron of the future, and he believed this because he had marked the astounding reduction which had been made in its price. He heard two iron manufacturers talking together the other day, and one accused the other of being a fool for selling steel at £13 a ton, but the other replied that he was much better off to sell 2,000 tons of steel at £13 than to sell 1,000 tons at £16. The conclusion he drew was, to even at £13, there was a jolly big profit, and he had no doubt that the price would ultimately come down to £10.

“Mr. Allen said that in building a steel bridge for the London and North Western Railway, they adopted five-eighths of steel as the proper proportion. As to the cost of steel, he could assure Mr. Scott Russell that it could not be produced at their works under £13 as the actual cost price.

“Mr. Grantham said that in the vessels he had mentioned the proportions adopted were two-thirds of steel to one of iron.”

68. *Steel Columns*.—“In France a few experiments were made some time ago by M. G. H. Love, upon small pillars made of Turton's steel, and having rounded ends. These pillars were one centimetre or 0·39 in. in diameter, the lengths being ten, twenty, and thirty times the diameter. The steel of which the pillars were composed was found by experiment to have a tensile breaking strength of 108,500 lb. per square inch. According to *Engineering*, the results show that, as in the case of cast and wrought iron, the resisting power of steel to compression decreases as the proportion which the length of the column bears to the diameter is increased; but this decrease in strength does not seem to be so rapid as in the case of the two first-mentioned materials. M. Love's own deductions are, that steel and cast-iron columns, having a length of from one and a half to five diameters, offer about the same resistance to compression; whilst columns of wrought iron of the same proportions offer only about half such resistance. When the length of the column is increased to ten diameters, however, he considers that steel offers a greater resistance than cast-iron, in the proportion of 41 to 31, the proportionate resistance of wrought iron being represented by 17. As the propor-

tion of length to diameter increases, the resisting power of cast-iron diminishes more rapidly than that of wrought iron, and that of wrought iron more quickly than that of steel, so that when the length reaches forty diameters, he estimates the strength of similar columns of the three materials to be in the proportion of the numbers 375, 562, and 1,500. It is wrong to found a law upon so few experiments; but, if the data above given are confirmed by future trials, steel will prove a valuable material for resisting compressive strains."—*Builder*.

69. *Steel for Railway Purposes*.—Under the above title the "Engineer" remarks:—"It has long been felt by all those in any way connected with the designing and erection of iron structures, the nature and position of which brought them under the surveillance of the officers of the Board of Trade, that it was high time an alteration should take place in the somewhat arbitrary regulations of that body from which there is now no appeal. Although it is universally admitted that the official regulation that the strain shall not exceed five tons per square inch of nett sectional area was not founded upon a satisfactory or conclusive basis, yet there is no question but it was as wise a rule as could be provided to meet general cases, and that it has answered the intended purpose well and efficiently. At the present time, however, when a formidable rival lays claim to the position so long enjoyed by iron as the chief of all constructive materials, it is manifest that, notwithstanding the efficiency of the regulation, it is no longer capable of application, and a change is imperative. With this object in view, a memorial has been addressed to the Secretary of the Board of Trade, requesting its consideration of the claims of steel as a substitute for iron, and drawing attention to the inapplicability of the present regulations respecting the working strain to be put upon the former material.

"Every engineer will regard with cordial approbation this attempt to break through the cordon of red-tapeism, which is in some measure an inevitable accompaniment of governmental interference, and to endeavour to procure that reform in the present railway regulations which will admit of steel being substituted for iron in a manner conducive to the honour of the profession, and in accordance with the principles of economy. It is obviously impossible, except at a ruinous and unwarrantable expendi-

ture, to construct steel bridges for passenger traffic under the existing laws of the Board of Trade. To place only five tons strain upon a material which will safely bear eight upon the same unit of area is equivalent to paying £1,600 for a structure which, while complying to the fullest extent with the requirements of strength and security, could be erected for £1,000. We heartily wish success to the memorialists in this important question; but, at the same time, we are not very sanguine in the matter. It must not be supposed that the object in view can be obtained off-hand; the Board of Trade neither would nor could, with a due regard to the gravity of the circumstances, decide summarily in the affair. Granting that the endeavours of the parties interested, which comprise every member of the profession, meet with the fullest success, it is not to be imagined for a moment that an immediate alteration in the rules will take place, and that engineers will be at liberty to employ steel with a strain of eight tons per square inch upon it forthwith. Such a course on the part of the Board of Trade would be in the highest degree imprudent and premature; and there is not the slightest doubt that before any change does take place, the officers of that department will have to be fully convinced of the accuracy of the statements respecting the strength of steel, and also will require a vast amount of further information respecting its various qualities. There is no difficulty in gaining this information; but it will take some time; and the great question that has to be solved is, who is going to supply it? In our last impression we suggested that a royal commission, similar to that conducted nearly twenty years ago, would be the best means of obtaining and utilizing the necessary information, and in all probability it would be the most efficient, authoritative, and trustworthy means of accomplishing a result which, sooner or later, must be taken in hand by some party or other. Although we are unchanged in our opinion of the merits of such a scheme, we are willing to admit that there are many difficulties to be encountered and obstacles to be overcome before it could be carried out. In the first place, a strong case must be made out before the petition for a royal commission will receive any attention, and, in fact, before it would even be presented. The profession could certainly make out a very strong case; but it is doubtful whether they could make out a case of necessity,

and this circumstance marks the distinction between the former commission and the one alluded to prospectively. The cases are by no means analogous. At the time when the former commission was issued, railroads were, comparatively speaking, in their infancy, iron bridges were a novelty, and it was in consequence of the danger to life and limb that resulted from their employment that the subject was taken up by Government. Again, very little was then known respecting the qualities of iron and its adaptability to the purposes it was put to; and the numerous accidents occurring were due in a great measure to the structures being designed by ignorant and incompetent persons. The sudden development of steam locomotion and the application of iron to railway purposes before its capabilities were ascertained and its powers thoroughly understood, left the majority of engineers little choice but to make their bridges many times stronger than requisite in order to ensure their being strong enough. Moreover, even if engineers as a body had desired to undertake an elaborate and costly series of experiments to convince themselves of the working properties of the material they were so extensively employing, the adequate means for accomplishing their purpose were not available, except at a price which precluded the very idea of the undertaking.

“It cannot be said that anything like an approach to a similar state of affairs exists at present. Iron structures do occasionally give way, and unhappy results ensue, but the cause cannot be ascribed to any incompetency on the part of the engineer connected with their construction; and limited as is our acquaintance with the qualities and capabilities of the metal steel, it is infinitely in advance of what our professional *confrères* possessed with relation to iron. With the imperfect knowledge at our command, we could construct at the present moment steel roofs and bridges which would present no such disproportion between their actual and necessary strength as characterizes many of the early iron structures. The object of the former commission was to supply a want and to furnish accurate and reliable information respecting the only material available for large railway bridges; while the object of the proposed investigation is to determine data respecting another material to be substituted for one which in one sense answers its purpose well enough. The more im-

portant question of the safety of the subject, which constituted the most prominent element of the commission of 1846, cannot be pleaded in the present instance. The Government is never prone to do for other people what they can do for themselves, and a very pertinent question here presents itself. Who are those who would most benefit by the substitution of steel for iron? Evidently the steel manufacturers. We do not for a moment begrudge them the well-deserved profits that would accrue to them in consequence of the success of the proposed measure. Quite the contrary. Many of the manufacturing firms and companies have by their own experiments, and also by the facilities they have afforded to engineers and others for obtaining sound and valuable knowledge, considerably contributed towards the fund of information we possess with respect to constructive materials, and we should sincerely rejoice to see them benefiting by an improvement which cannot fail to be serviceable to nearly every branch of engineering art. On the side of fairness and justice it may be submitted that those who are to benefit commercially by the results of the inquiry, whether private or public, are naturally expected to bear their share at least of the cost and trouble accompanying the investigation. Many will probably be of this opinion, and we feel pretty certain that the parties concerned would not hesitate to bear their share of the burden, being well assured that the objects to be gained by such an inquiry would prove a source of profit and remuneration to themselves, and a valuable addition to the *repertoire* of engineering facts and data. The excuse that an investigation, comprising a series of experiments upon the merits of steel, could not be carried out independently of the aid of Government, is not now available as it might have been twenty years ago.

“There are premises in London which offer every facility and convenience that could be required, and if additional accommodation and machinery were found to be indispensable towards the proper fulfilment of the necessary conditions, they could very easily be provided. We are ready to believe that the Government would be willing to second any effort made for the advancement of science, more especially when relating to so practical a department of it as that belonging to railway engineering. The substitution of steel for iron would perform but a very small part of

the duty that will ultimately devolve upon it, if we were to confine our labours to simply erecting structures of that material, having their fac-similes already existing of iron. The real value of the substitution will consist in applying the stronger and lighter material to purposes which we could not hope to successfully accomplish with a material possessing inferior qualities. The gentlemen whose signatures are appended to the communication which has formed our present topic have made a step in the right direction. They have broken the ice, and it only remains for their efforts to be seconded in order to clear away all obstacles, and ensure a fair field for the development of the powers of our new mechanical ally."

70. *On Honeycombed Steel Castings.*—From a lecture by M. Caron read before the French Academy, and which has been translated for and published in "Engineering," we take the following:—"The castings of steel, particularly those of the softer kinds of that material, are very liable to become porous and honeycombed. For avoiding those honeycombs, or at least for reducing the sizes of the holes and bubbles, it is the general practice in casting steel to close the ingot moulds immediately after casting. The principal effect of this is to cool down the surface of the liquid metal, and to prevent the gases from the interior escaping and forming those large bubbles which deteriorate the quality of the steel. The holes observed in steel castings are of two different kinds. Some of these cavities appear to have a perfectly metallic surface, and seem to be produced by some gas which is incapable of oxidizing the metal, while the other kind of bubbles presents to the eye a coloured surface the same as exhibited by iron or steel after being heated in the open air. The holes of the first kind are more numerous and prevail in the centre of the ingots, while the latter generally appear in the vicinity of the outer surface only. It is universally assumed that the film of oxide of iron which produces the colour upon the interior surface of the holes, is due to the action of free oxygen enclosed in the bubble in the moment of its formation. With regard to the other holes, if we take into consideration the nature of the atmosphere and of the substances in contact with the metal during its fusion, it is certain that the only gases by which these can be produced are hydrogen, carbonic oxide, nitrogen, or a mix-

ture of these gases. Analysis could give information on this subject, but unfortunately the first difficulty which presents itself, and which appears to be almost insurmountable, consists in collecting these gases in a sufficiently pure state. The researches in this direction have therefore not given any sufficiently reliable results. It has therefore been preferred to take another course of investigation.

“The gases which form the bubbles may come from the atmosphere of the furnace, and be absorbed by the metal in fusion, or they may be generated in the interior of the liquid mass.

“Steel melted in a crucible of fireclay, and allowed to cool slowly, is always filled with cavities, sometimes even, when the gases of the former have penetrated into the crucible in greater quantities, there is a creamy metallic efflorescence on the top of the ingot which occupies a considerable volume. This is never observed with cast iron. With the exception of a central cavity which is sometimes formed by the shrinkage of the material, the castings of iron are always perfectly sound, and the introduction of the furnace gases into the crucible never causes any boiling efflorescence. These facts, which have been ascertained by repeated experiments, allow of two suppositions. Those who assume a direct absorption of the gases from the furnace may presume that the steel possesses the faculty of absorbing these gases, while iron does not possess the same. The others, who do not admit a direct absorption, will think the bubbles to come from gases generated by the action of the carbon in the steel on some substances mixed or combined with the molten metal. For ascertaining which hypothesis is correct the following experiments were tried. Steel was melted in a porcelain tube, with currents of hydrogen, carbonic oxide gas, &c., passing through the same, in order to prove the presence or absence of honeycombs under the influence of these gases. The results obtained are as follows: Steel melted in a porcelain vessel, in an atmosphere of hydrogen or carbonic oxide, produced an ingot without any efflorescence on the top, but with a surface full of cavities similar to those observed in castings from the clay crucible. The outer surface being in contact with the porcelain, the question arose whether the nature of the vessel had any influence upon the result obtained. A vessel of magnesia, and afterwards one made of burnt limestone (chaux

vive), were substituted, and separated from the porcelain tube by a piece of platinum. With these precautions ingots of perfect soundness, free from all cavities, efflorescences, or honeycombs, were produced. These experiments show clearly that it is not the hydrogen or carbonic oxide absorbed by the liquid steel by which the air-bubbles are produced. There only remains, therefore, the supposition that honeycombs are produced by gases generated within the liquid mass; and the principal causes for this seem to be, first, the oxidizing influence of the atmosphere in the furnace upon the iron which, in contact with the silica of the crucible, forms a silicate, and the subsequent decomposition of the silicate of iron by the carbon contained in the steel.

"Having, by the above experiments with different gases and vessels, established the influence which the atmosphere in the furnace and the nature of the crucibles can have upon the quality of steel, M. Caron attempted to approach more closely to the conditions existing in practice.

"Two pieces of steel from the same bar were taken. One was placed into a fireclay crucible, the other into a crucible cut out of a lump of burnt limestone. These two crucibles, furnished with proper covers, were placed each within another crucible of fireclay, being separated from the outer crucible by an infusible wadding. They were heated in the same furnace under perfectly equal conditions. After four hours, the crucibles were taken out and broken when cold. The steel had been in perfect fusion in both cases, but the clay crucible had produced a rough and honeycombed ingot, while the lime crucible gave a perfectly sound ingot moulded exactly to the shape of the vessel. By employing magnesia instead of lime, the same effects were produced. It is comparatively easy to make magnesia crucibles by pressing that substance into suitable moulds. They are very durable, and resist the fire very well even after repeated heating and cooling and exposure to air and damp. Magnesia and lime do not form any fusible compounds with the oxide of iron, and therein differ from silica, which forms the main component of the refractory substances in general use at present. It would be desirable to substitute magnesia or lime for the silica in the manufactures, but the present price of magnesia is still too high, being 250 francs, or £10 per ton.

"There remains one point yet to be considered which the above experiments have not sufficiently cleared up. Liquid metals do not as a rule give off the gases contained in them until they reach the point of solidification. This can be easily observed with copper, silver, platinum, &c. Steel possesses the same property, and it seems that there is a certain analogy between all these facts. The following experiment has been tried with a view of forming an explanation, though it may be only a hypothetical one.

"The following substances were melted in fireclay crucibles, and allowed to cool slowly, viz., white iron, soft steel, hard steel, and grey cast iron. The ingot of white iron had no holes, the soft steel ingot was filled with bubbles, the hard steel contained considerably less, and the grey iron, although free of holes, exhibited by the solidified drops on the lid of the crucible the previous existence of an ebullition.

"Let us suppose that all these metals absorb oxygen, but that this substance, although in contact with the carbon in the steel, could not produce carbonic acid except at a temperature which very nearly coincides with the melting point of soft steel, and which therefore is considerably higher than the point of solidification of cast iron. It would then follow that the carburets of iron will produce carbonic oxide gas at a certain temperature which will escape from the liquid mass, and which will form bubbles and honeycombs whenever the melting point of the metal approaches the temperature at which the reaction between oxide of iron and carbon takes place.

"This explanation, although founded on a hypothesis, well corresponds with the facts observed, and it may be useful for indicating the means to get rid of the air holes in steel castings, which is one of the most difficult problems in modern metallurgy."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION SEVENTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

Galvanizing Apparatus,—*Engineer*, p. 308, Oct. 26th, Illustrated.

Steel Rails,—*Engineering*, Nov. 16th, p. 371.

The Cyclops Steel Works,—*Engineering*, Nov. 16th, p. 372.

Wear of Iron Rails,—*Engineering*, Oct. 5th, p. 248.

- Railway Bars, Manufacture of*,—Mech. Mag., Oct. 5th.
Iron Plate Working,—Engineering, Feb. 2d, p. 74.
Moulder's Sand,—Engineering, Sep. 28th, p. 242.
Strength of Bessemer Cast Steel,—Engineer, April 27th, p. 300.
Cast-Iron, Wrought-Iron, and Wood in Compression,—Engineering, Aug. 17th, p. 107, Illus.
Zinc and the Société de la Vielle Montagne,—Engineering, June 8th, p. 378.
Covering Metals with Bright Coating of other Metal,—Scientific Review, March.
The Hæmatite Mines of the Alverstoke District,—Engineer, June 29th.
On some Points of Practice in Iron Foundry,—Prac. Mech. Jour., in Nos. for January, February, March, April, May, August, Sept., October, November, Dec., Illus.
Lead and Lead-Work,—Building News, Nov. 2d.
Papers on Puddling,—Commenced in No. of Engineer, Jan. 19th.
Steel as a Material for Future Engineering Construction, by J. Scott Russell, —Engineering, Feb. 9th.
Chilled Castings,—Engineer, Nov. 9th.
Cleveland Blast Furnaces,—Engineering, Jan. 12th, Illus.
Iron Plate Working,—Engineering, Feb. 2d.
American Blast Furnaces,—Engineering, June 1st, Illus.
Steel in Construction,—Engineering, March 2d.
Bessemer soft Iron,—Engineering, Sep. 21st.
Mechanical Treatment of Ores,—Engineering, July 27th, p. 54, Illus.
On Treatment of Melted Cast Iron, and its Conversion into Iron and Steel by the Pneumatic Process,—Engineer, Aug. 31st, p. 161.
Official Recognition of Steel in Construction,—Engineer, Nov. 9th, p. 356.
Galvanizing,—Eng. Mech. and Mirror of Science, March 9th, pp. 346, 347.

DIVISION EIGHTH.

RAILWAYS.

71. *On the Permanent Way of Railways*.—Under the above title Mr. R. Richardson, C. E., read a paper before the "Inventors' Institute," which we here give:—"The term, 'Permanent Way,' is employed to distinguish the iron-edge railways, on which we travel, from the old cast-iron tramroads, and from the temporary wrought-iron ways used by contractors in the construction of railway earthworks.

"For constructing these works, the temporary, or contractors' way, is beyond doubt a great advance upon the old Dobbin carts which are still used for removing earth in the formation of docks and canals.

"A contractors' way is made up of light wrought-iron rails spiked down to transverse wooden sleepers. It is strong enough to carry two or three tons of earth in each waggon. The old cast-iron tramroads were principally used for bringing coal from the pit's mouth to the shipping ports. A short time before a railway is opened for traffic, ballast is spread over the line, and the contractors' or temporary way is replaced by heavier rails and larger sleepers. These constitute what is appropriately called the Permanent way: and to this I intend, as far as possible, to confine my remarks in the paper which I now bring before you.

"From the beginning of this century to the present time there have been many experiments and trials of new inventions for permanent way, but without practical results of any great importance; for many inventors, ignorant of what had already failed, have re-invented and tried the very same supposed improvements over and over again, each in his turn being unwilling to admit that his scheme was not new. Some of the first inventions sufficed to produce a good ordinary permanent way; and, with the exception of some important improvements in details, we find ourselves, after a lapse of more than thirty years, using very much the same sectional figure of wrought-iron edge-rail as was then adopted.

"Besides the transverse sectional forms of cast-iron trams and wrought-iron edge-rails that have been more or less used or suggested, there are very many other slight sectional variations used in repairing roads; for engineers are seldom satisfied with those adopted by their predecessors.

"In Mr. Smiles' 'Life of George Stephenson,' he says that a Mr. Beaumont employed wooden rails as early as 1630. According to another author, he laid them near Newcastle in 1602; but, as might be expected, little encouragement was at that time given to the invention. According to Mr. Nicholas Woods, the books of the Colebrook Dale Company furnish reliable evidence that in 1767, five or six tons of rails were *cast*, and from about this time dates the birth of cast-iron rails. They were probably angle-irons for some tramroad: for it is elsewhere mentioned that an iron tramroad was laid down near Sheffield, by Mr. John Curr, in 1776, which was destroyed by the colliers. That this was merely a tramroad is confirmed by the fact that, three years after,

Mr. William Jessop first used cast-iron *edge-rails* as a new invention.

In 1814, light wrought-iron square bars, two feet long, were imported from Sweden. They were laid on longitudinal timbers, by Mr. G. Stephenson, on the Killingworth Colliery Railway. Rails are now rolled as long as thirty-five feet. Two years afterwards, the same gentleman patented a cast-iron edge-rail, which he soon abandoned, returning to wrought-iron edge-rails. Up to this time, railways for the public transit of passengers were not used to any extent, and little was done until 1825, when Mr. G. Stephenson adopted Mr. Birkenshaw's patent fish-belly wrought-iron rails for the Stockton and Darlington Railway. This last kind of edge-rail was laid on the Liverpool and Manchester Railway in 1829, for the competitive trials of locomotive engines, which were to run only by the simple adhesion of their wheels on the rails. Before this time, locomotives had been armed with cog-wheels, that geared into iron racks laid down upon the road to assist their propulsion. It is worth while observing that this company at one time seriously contemplated carrying only goods, some of the directors thinking that to carry passengers was not worth their attention, and would never pay. The first Parliamentary sanction for an iron tramroad was granted in the year 1801, for a line from the river Thames at Wandsworth to Croydon. Wrought-iron fish-belly rails were in after years proposed by Mr. I. K. Brunel for the Great Western Railway: and a model was exhibited by him to the Committee of the House of Lords, previously to the company receiving their Act of Parliament in 1835.

"Before the present great railway system was carried to any extent, Mr. Henry Robinson Palmer, an engineer of surpassing ability, and one of the founders of the Institution of Civil Engineers, invented a railway having only one single rail to travel on. The rail was elevated more or less above the ground, and upon it was placed a wheeled saddle, from which panniers to carry passengers were suspended on either side, as they are from the back of a mule. To this carriage a rope was attached, and it was drawn along by horses. About a mile of this road was laid at Cheshunt in 1830, and another length was laid shortly afterwards in Woolwich Victualling Yard. Mr. Palmer then proposed a double elevated

railway, so as to enable the centre of gravity in the carriages to be brought nearly down to the level of the rails. This scheme was abandoned, as being too expensive. The next change in the form of edge rails was made by Messrs. Stephenson and Locke, and with their united thoughts they produced a double-headed rail. This rail was simply fastened with a wooden key into a cast-iron chair, which was spiked down to transverse wooden sleepers, or fastened to stone blocks. Mr. I. K. Brunel soon abandoned his first theory of fish-belly rails, and narrow gauge, for a hollow single-headed rail and a seven feet gauge, which is the system still used on the Great Western line. This rail is screwed down to a longitudinal timber, and between the two are placed thin slips of hard wood, with their grain running across the sleeper. A somewhat similar solid rail was invented by Messrs. Stephenson and Vignoles. This rail is now universally used throughout France. It is screwed down to transverse wooden sleepers with galvanised iron-wood screws: and, to prevent the workmen from driving instead of screwing them, a little detector is raised on the head of the screw. About twenty years ago the traffic on railways began rapidly to increase, and the great cost for upholding and repairing railways was sorely complained of. With a view to economy, Mr. W. H. Barlow invented a rail, in which both rail and sleeper were rolled in one length of metal. This rail takes its own unaided bearing in the ballast, and has the least number of detached parts of any system to keep in repair. It has done great duty on the Midland line, between Gloucester and Stonehouse, for the last twelve years. Though somewhat harsh to run over at high speeds, for lines of light traffic, and where the decay of wood is rapid, such rails form a most economical system in construction and maintenance.

“Some speculative minds have thought it necessary to make a permanent way elastic. This is fallacious for many reasons, and would be extremely dangerous to travel on at high speeds. What is required is a way that will absorb the violent concussions of blows of a heavy locomotive engine, and only just sensibly yield to the passing load; but this impression on the rails must not on any account amount to elasticity, in the true mechanical meaning of the word. Again, the other extreme of a very deep and very rigid rail has failed, partly because the top

surface of the rail spreads out or crushes under the weight before it becomes fairly worn, and this is caused by the unequal expansion and contraction of the metal between the top and bottom surfaces, as they never can be placed in an equal temperature. The vertical section of a rail, to secure this *desideratum* of contraction and expansion, should never exceed five inches; for even in England, in summer weather, the temperature of the top surface is often as high as 130° Fahr. in the sun; and there is a sensible ringing noise as the temperature alters by the passage of a cloud in the sky, which is a sign that contraction has gone on throughout the depth of the rail, and that the fibres are not being displaced, as they must be in a very deep rail under the same circumstances.

“There have been no striking improvements in railway chairs, nor do they seem to admit of any, except in the proper admixture of metal in their manufacture. They have been cast solid, and rolled in two parts, to dispense with wooden keys, and the keys have been drawn in place by screws, but no advantage has been gained. They must be simply attached to the rail, and any complicated arrangement only increases the number of parts to be kept together. Railway keys have been made of many materials—papier-maché, rolled iron rings, cast-iron, and wood. They have been made in one, two, and three parts, and driven or screwed into the chair both vertically and horizontally. The spikes to fasten the chairs are sometimes hollow, at others solid, twisted, or split. They are driven at almost every angle into the sleeper.

“I will now refer to the schemes for securing the rail joints. Until 1847, double-headed rails were simply fastened by a wooden or iron key in a cast-iron chair. The rail-ends were constantly parting, and under traffic the incessant tipping of the rails and joint-sleepers involved a serious expenditure for maintenance. With a view to mitigate this evil, in 1845 and 1846 I suggested and carried out some practical experiments, by removing the joint-chair and suspending the rails at the joints between two common intermediate cast-iron chairs on sleepers, through which one long wooden key was driven on one side of the rail only. This answered beyond my expectation. It prevented the longitudinal tipping, and greatly reduced the cost of maintenance. Improvements in this arrangement, one of which was the appli-

cation of two wedge-shaped iron keys instead of one long wooden one, with other schemes for this purpose, were secured by me, in conjunction with Mr. W. B. Adams, by letters patent, and called by him fish-jointing. We then bolted the fish-plates to the rails, and, after some four or five years of further experiments solely through the determination of the Permanent Way Company, the system began to be appreciated; and fish-jointing, with its improvements, has now, under the guidance of this company, gradually spread wherever railways exist. The annual saving in maintenance, with all its collateral advantages of safety and diminished wear and tear of rolling stock, amounts annually to millions. Mr. Woodhouse, of the London and North Western line, gave in evidence that, by the use of suspended fish-joints, there was, on his line, a saving of seventy-five per cent. in maintenance—an economy which, in other words, represents a dividend. Several improvements in fish-jointing have since been made; and the rapid increase in the use of Mr. William Pole's invention of tapping one fish-plate to dispense with nuts, is fast superseding all other plans for new lines.

“With the present traffic on railways, the bearing surface of sleepers should never be less than 10 sq. in. per foot forward on a 4 ft. 8½ in. gauge, this surface increasing as the gauge widens. Sleepers have been made of earthenware, stone, cast iron, wrought iron, and wood—the last being the material most employed, on account of its cheapness, and because it is thought to dispense with the harsh sensation which is supposed to be caused by iron sleepers, but which is often due to many other circumstances. One of the advantages of timber is its great dead weight; and if it were not for its rapid decay, and destruction under the chairs and fastenings, no material could be better adapted for sleepers in cold climates. The durability of wooden sleepers is in some measure increased by the use of preservatives. They have been charred, soaked in salt water, and in solutions of mercury, zinc, lead, iron, oil, tallow, resin, creosote, and sulphate of copper. This last-mentioned material is very valuable, and, through the kindness of the Permanent Way Company, I am permitted to offer the members of the INVENTORS' INSTITUTE copies of Dr. Boucherie's pamphlet, descriptive of his process for preserving timber sleepers from decay, by forcing a solution of sulphate of

copper through them. His experiments have now extended over twenty years. In hot climates, besides decay, accelerated by the high temperature, the ravages of white ants and other insects render even preserved timber worm-eaten, and the preservatives make them brittle; consequently, other materials must, for economy, be used. Of these, cast iron is, beyond doubt, the best. It possesses many advantages; it has a thick hard crust, to resist oxidation; its dead weight is considerable; it is easily re-cast when broken; it may be constructed so as to present a great bearing surface, and to be free from what is called swerving and rocking; and by proper arrangements, rails laid on cast-iron sleepers may be made quite as easy to travel over as when they are placed in cast-iron chairs on wooden sleepers. Many miles of cast-iron sleepers, the invention of Mr. P. W. Barlow, have for the last sixteen years been under traffic on the South Eastern Railway in the neighbourhood of Hastings, and for fifteen years on the Enniskillen line. On the Great Eastern line, Mr. James Samuel laid down some timber-bedded cast-iron sleepers, which were under heavy traffic for ten years. These sleepers, with their timber linings, possess the merit of having great strength and dead weight. Mr. Hugh Greave's system of sleepers, made like inverted bowls, has been for many years used in Egypt, India, and Brazil. Mr. De Bergue's circular plates are used in Spain, and Messrs. Livesey, Griffin, and other gentlemen, are engaged in laying down cast-iron sleepers, arranged according to systems invented by them. A few years ago the Permanent Way Company prosecuted a series of experiments for ascertaining the breaking strain of cast-iron sleepers, the results of which were presented to the Institution of Civil Engineers; and I am still engaged in preparing experiments on a new form for cast-iron sleepers. Mr. Wilson is at present laying corrugated wrought-iron sleepers on the Indian Branch Railway, though as yet there has been little experience as to their durability.

"It is far beyond the limits of a paper like this even to refer to the many inventions that have been made for permanent way; I must, therefore, as much as possible, confine my attention to the bare outlines of the general principles which should regulate the construction of a good road. Some kinds of permanent way answer very well in one locality, but often fail in another; and

what makes a tolerably good road in one kind of ballast may soon go to pieces in ballast of another description. It is, therefore, impossible to devise any particular system that is the best under all circumstances.

"The proper laying out of railway curves forms a very important feature in their construction, and great care must be taken to increase the width of the gauge as the radius of the curve diminishes. To permit of a high speed on curves, the outside rail must be elevated more or less, to suit the maximum speed and radius; in a word, gauge and elevation of outside rail have to be accurate, but not uniform; and when this is carefully done, slight curves, instead of being objectionable, are preferable to straight lines for high speeds, for they give steadiness and even pressure in the one direction or the other, while the straight line causes constant vibration. When a railway cannot be made level throughout, to work with economy, the necessary inclines should be short, and constantly falling and rising. On a line with very steep inclines the top surface of the rail is sometimes more rounded than on a level line, and when the metal is soft, an engine can ascend a steeper incline on such rails than on those which have a flatter surface; but this necessarily implies destruction of the rails. I know of a case where an engineer of a railway laid down rails considerably rounded, on an incline, in opposition to the wish of the locomotive engineer, who declared he would soon flatten them; and with the hard steel tires of his locomotive he shortly fulfilled his promise, so that the rails were soon worn out, and had to be removed. If Mr. Bessemer's steel rails had been employed, there is little doubt that the result would have been the other way; for, on the London and North-Western line, one of his experimental steel rails has worn out eighteen faces of common rails. I will now devote a few words to turn-tables and switches.

"In turn-tables, very few improvements of any importance have been made since they were first introduced. Where there is not sufficient room to work them, Mr. Dunn's traverser—which may be seen at most large stations—is very useful and ingenious, as a substitute for them. Before the invention of switches, by which an engine is enabled to run out of the main line on to a siding, two main line rails were made to turn out, so that their

ends came in line with the first two fixed rails in the siding. This arrangement was the cause of many accidents, to avoid which Mr. Curtis invented his double-shifting turn-out rails; but still accidents from running off continued, until Sir Charles Fox invented and patented a safety switch, by the use of which it became impossible for an engine to run off the rails. Sir Charles notched the main rail to receive the point of the switch, and Mr. C. H. Wild, by housing the point under the top flange of the main rail, dispensed with this notching, and thereby strengthened the main rail. The point of a switch may be made very stiff, and, at the same time, effectually prevented from jumping up, by housing the end under both the top and bottom flanges of the main rail.

“Among the worst faults in laying out a line are incorrect elevation of the outer rails in curves, irregularities in the tilt and gauge, want of sufficient ballast and of room for expansion in the rails, deficient bearing surface in the sleepers, imperfect drainage, and bad iron. These are some of the worst features in the fixed portions of the work, the destruction of which is accelerated by bent carriage-axles, oval worn wheels, and inequality in the springs of the engine and of the carriages, which produces a jumping motion. Straight lines form the source of another kind of evil. When passing rapidly over them there is a zigzag motion given to the engine and carriages, by which not only the rolling stock, but also the line, is soon thrown out of repair. There is no doubt that the wider the gauge, the greater may be the motive power; but it does not necessarily follow that the safety is increased by a wide gauge. This is fully borne out by the practice on the Festiniog 2-ft. gauge railway, which has proved to be as safe as a 7-ft. gauge. Almost every gauge has been employed, 2 ft., 3 ft., 3 ft. 4 in., 3 ft. 6 in., 3 ft. 7½ in., 4 ft., 4 ft. 8½ in., 4 ft. 11½ in., 5 ft., 5 ft. 3 in., 5 ft. 6 in., 6 ft., 6 ft. 2 in., and 7 ft. Often, where the traffic is not sufficient for a broad gauge, it becomes remunerative on a very narrow one; the gauge may represent the requirements of a district, and should, as far as possible, be determined according to those requirements. It may be taken as an axiom never to be lost sight of, that freedom from noise implies perfection in travelling, as it does in arresting destruction; for whenever there is noise, there must be friction and

heat, which are the prime causes of all destruction of materials.

“In conclusion, I may observe that travellers are by no means aware of the almost daily improvements that are gradually going on throughout the entire rolling stock and permanent way of railways. They would more fully appreciate these improvements if they could run out of a first-class line, at a high speed, on to one of the old original lines, such as the Liverpool and Manchester, with its rattle and jolting. Now, indeed, it is far more safe for one to be continually travelling than to pass an active life under almost any other conditions. This statement is borne out from the official returns of the persons whose deaths were due to causes beyond their own control on the railways in the United Kingdom. Their number has decreased from 38 in 1844 to 23 in 1859, and to only 15 in 1864, while the numbers that travelled during the last-named year amounted to the enormous figure of 229,350,000, or nearly eight times the whole population of the kingdom. Thus the chance of death is 1 in 15,290,000, which may be taken practically as no chance at all. Let this be compared with the liability to fatal accident from horse conveyances in London alone, with its population of nearly 3,000,000. By the returns from the Registrar-General's office during the year 1865, there were 215 persons killed by horse conveyance, or 1 in every 14,000 of the population. The railway return already quoted gives a result of 1 in every 2,000,000 of population, or one in every 15,290,000 of travellers; so that, taking this estimate by population, the railways are 150 times more safe than the streets of London; while, if it be taken by the numbers travelling, they are nearly 1,100 times more secure against fatal accidents.”

72. In connection with the working of railways with exceptional gradients, such as those met with in the Mount Cenis Railway, a Continental engineer has made a proposition of a very novel kind under the title, *The Application of Hydraulic Power to the Working of Mountain Railways*.—The “Engineer” has an article devoted to the proposition, which we here give:—“Few subjects are now engaging more attention than the working of high gradients, and a variety of schemes, more or less new and successful, are being tried. Our attention has been directed

to a fresh project which, at first sight, possesses almost startling novelty. It is no less than a proposal to apply the immense hydraulic power continually descending the sides of most chains of hills to working up the trains of the mountain lines. The unceasing action of the sun in evaporating the waters, and depositing them back on the high peaks of the earth, may be said to constitute a perpetual motion ; and it is this perpetually moving power which it is proposed diurnally to utilise. The scheme may be briefly stated to consist in combining the experience lately acquired in the accumulation and transmission of power by means of air compressed by the hydraulic power of large bodies of water, with the experience and data acquired in working railways pneumatically. In one word, it is an amalgamation of the mode employed for accumulating the power directed to cut the Mount Cenis tunnel, with the experience gained in London with the new system of pneumatic railways. However bold the scheme may seem at first, we feel confident that any reader of the able pamphlet before us will be induced to think favourably of the plan. If it should ever come to complete maturity everything points to Switzerland as the country where this would take place.

“As M. Dapples, the author, begins by observing, that country possesses immense stores of motive power in the enormous volumes of water condensed and deposited on the great heights of her mountains. The wants of European commerce require that these heights should be passed ; but the cost of vertical transport is necessarily much higher than that on a level. Enormous weights of water are continually descending the upper valleys, considerably exceeding the weight of any possible amount of traffic ; and these volumes of water necessarily choose the same path of the weights that are to be carried up. To apply these hydraulic forces is an obvious thought ; a mode for their application and transmission has to be found out by the engineer. Two plans here at once present themselves ; the transmission of motive power to the train by means of ropes or chains ; or its transmission by means of a fluid current of water or of atmospheric air. Robert Stephenson, in a report addressed in 1862 to the Swiss Federal Council, recommended for the passage of heavy gradients the use of the weight of the descending trains, some of the carriages of which were to be filled with water, in order to aid the ascent of the

next gradient. In the Italian department of the western annexe of the Exhibition of 1862 was exhibited a rope system on the plan of M. Agudio, according to which the locomotive dragged itself up by winding up a rope round a drum. M. Agudio also proposes to drive the drum on the 'locomotive' by means of two smaller ropes, driven by a fixed engine. The system is said to have afforded good experimental results in Italy, but, though probably the most improved form of the funicular plan of traction—from its doing away with the weight of a long length of rope—it is not freed from all the well-known difficulties of rope traction. Directly to take a current of water itself would be impracticable, on rather long gradients, on account of its weight. On the other hand, the success with which the atmosphere has been used to transmit power to great distances points to it as the most practicable agent. The pressure and movement can be produced either by exhaustion or compression; and once obtained, they can be communicated to the train either by acting directly on the whole surface of the train—as in the new pneumatic system or on a smaller piston attached to the train, placed in a smaller pipe. The first and newest plan has been found the most successful, because less pressure is required, and because it is not necessary continually to seal a long longitudinal joint—a difficulty which was the main stumbling-block of the old system of atmospheric railway. Mr. Rammell has, in fact, shown the practical feasibility of the pneumatic system for the transmission of parcels, and an extension of his system will doubtless soon be in practical working for actual passenger traffic.

“His success has stimulated the Swiss in their attempts to utilise the immense hydraulic power of their valleys. Another Swiss engineer, M. Bergeron, has written a pamphlet advocating the application of the pneumatic system, and asking for a concession to establish an experimental line between the town of Lausanne and the present railway station. In the meantime an ingenious apparatus, termed the 'aëro-hydrostatic balance,' was being brought forward by M. Seiler, a member of the National Council of Switzerland, for raising entire trains from one level to the other. We remember to have seen a large model of the apparatus in the western annexe of the 1862 Exhibition. It was not mentioned in the Jury Reports, because it was only set up

towards the termination of the Exhibition. It has, we believe, been patented in this country. It may be described as a sort of pair of scales, in which the two scales of the balance consist of two bells reversed in a water tank. The air contained in the two bells can freely communicate by means of a tube, so that, in causing one of the bells to descend in the water by means of a surplus load, the air is forced to pass by the tube under the other bell, thus raising it at the same time. M. Dapples thinks that this 'balance' can be applied to raise large weights; to replace canal locks; to raise and lower, either vertically or on an inclined plane, railway trains; or even to accumulate compressed air, and to inject it, in any direction, into any receptacle—becoming a hydraulic prime mover when worked by a surplus load of water. Several Swiss engineers are stated to have formed the opinion that it could be used as a 'blast bell,' *cloche soufflante*, so to speak—as in fact, a blowing apparatus for working railway trains on the pneumatic system.

"The great scale upon which, in the Mount Cenis tunnel, air is being successfully employed for transmitting power, had, in fact, long ago directed the attention of many persons in Italy to its use for working the Alpine lines. M. Berrens wrote, in 1861, a work on the question; another Italian engineer proposed two balanced tubes for applying the weight of the descending to the ascending trains; Mr. Edwards, an English engineer, exhibited in Turin, a model of a pneumatic railway; M. Sommelier reported, in 1863, that the application of air to this purpose was a problem that would soon be solved. M. Perdonnet, the distinguished French locomotive engineer, properly concludes that the atmospheric and the rope traction systems would be quite inadmissible in long level lines of railway. But the working conditions of a series of heavy gradients are very different. As regards steep gradients, he considers that at slow speeds rope traction would be superior to the atmospheric system; but that at high speeds the reverse would be the case. The atmospheric system is also much preferable to ropes when sharp curves have to be encountered; but the first cost of its application is much higher; while both systems have the objections of being inconvenient at the stations, and of rendering it difficult to meet any momentary increase of traffic.

"The objections common to all systems of locomotion with

fixed engines are thus, the dependence of the traffic on one main agent—the objections as to getting at the trains at the stations—those respecting the expansibility of the working—and the impediments to level roads. These objections, however, as M. Dapples shows, lose much of their importance in a mountainous country with an abundance of hydraulic power, where the atmospheric system would only be employed in certain sections with heavy gradients, and where the roads to be passed at a level are but few. The special objections to the atmospheric system are its high first cost and its expensive working. These objections are also of less importance for mountain lines. Long tunnels would be saved—much of the works would, in any case, have to be covered up from the winter snows—and working power would be obtained at a rate represented by the interest on the first cost, the depreciation, and the expense in repairs of the apparatus for its accumulation and transmission. No expensive ropes and rubbing surfaces have to be kept in repair; and favourably differing in this respect also from the funicular system, the pneumatic railway affords greater security in cases of accident, from the facility of stopping a train by means of the piston carriage. Again, both a plenum and a vacuum blast can be used, which permits a wide choice in locating the prime mover. The result of an elaborate discussion thus places the pneumatic plan considerably ahead of rope traction for steep inclines and sharp gradients. On the other hand, as regards the future of working steep inclines by means of locomotives, no one would assert that the limit of what is possible has been attained. A number of different excellent plans, proposed by a body of able engineers, are now in actual practical competition. Some of these also take changes in the line into account; the most successful of these being that of Mr. Fell. Agudio's plan, when working with a rope wound upon a drum attached to the locomotive, would also come under the head of that system which seeks to supplement the ordinary adhesion between the smooth wheels and rail. But the use of a locomotive means the neglect of the enormous and truly inexhaustible stores of power to be found in the ever-descending torrents from the mountains. At a less working expense in fuel than is naturally required by locomotives on steep gradients, the system of long tunnels has the inconvenience of an

enormous first cost. It often means loading an undertaking with a first cost of at least two or three millions sterling, without any saving of motive power beyond that acquired by avoiding steep gradients."

73. *Rails and Wheels*.—On these subjects we give here articles taken from the sources named. (a) *Life of a Rail*.—"In the whole of the wide range," says a writer in the 'Mechanics' Magazine,' "embraced by the application of iron to the various purposes of engineering and construction, it would be difficult to find an example which, for the time it is in use, undergoes a more *pénible* existence than a rail. We, of course, allude to the rails forming a portion of the permanent way of our main lines of railway. A rail is nothing more than a small beam or girder of a very short span under a very heavy load. It is hardly correct to state it as under a load, since the load assumes the conditions of a series of shocks, and affects the rail by the force of impact or percussion. Combined with the peculiar action of this force, concerning the real nature and effects of which very little is known, there is the wear and tear of that portion of the rail exposed to the direct destructive influence of the driving wheels of the engine, and, in fact, to every other cause tending to injure and deteriorate the material. It is to the necessity of resisting this combination of forces, that is to be attributed the difficulty of procuring rails of a durable character. The properties of a rail, so far as they are identical with that of a girder, can be readily obtained by the degree of strength requisite to bear the percussive load without deflecting to an extent greater than what would be considered safe. It is the surface of the rail, or rather the top of the rail, which has hitherto baffled all attempts to impart to it qualities enabling it to resist injury in a degree commensurate with that exerted by the contiguous parts. In the employment of any material, in a situation analagous to that of a rail, where it is known *à priori* that after a certain time has elapsed it will be no longer competent to perform its duty, but will have to be replaced by a new one, the great object in view is to use as much of it up, or in other words to utilize it as much as possible, before it is obliged to retire from service. If we had a certain number of square inches of iron in daily use, we should only have obtained the maximum value out of it when, in discarding it, the

whole area had been uniformly determined, or subjected to an uniform wear and tear, and had become in fact what is termed 'regularly worn out.' From peculiarities of form and various other circumstances, we do not suppose that this theoretical value could ever be obtained; some loss or some comparatively sound material must always accompany any worn out examples whether of iron or other substances. The principle may be thus explained. Let S represent the superficial area per unit of length of that portion of a rail exposed to the wear and tear of the wheels, brakes, and other destructive causes, and put C for the cubical contents of the same length, then the value of the rail, so far as its durability is concerned, will be directly proportionate to $\frac{S}{C}$. In rails there is a minimum value of C which must be adhered to, or the rail would be too weak to do its duty. Any increase of C beyond what is necessary to afford the required strength, is evidently a complete waste of metal. There would be no advantage gained in making rails twelve inches deep instead of four or five, provided the surface under attrition were the same. The proportion which the wearing surface of the head of the rail bears to the sectional area of the whole rail will also express pretty accurately the value of its durability. Allowing a liberal margin of two inches for the tread of the wheel, it will be seen that not more than one-twentieth of the actual metal in a rail is utilized before it becomes unfit for traffic, and must be either laid down in sidings or sold for 'old rails.' Taking this profit into account, there is very little doubt notwithstanding, but that 25 per cent. of the metal in rails is altogether unremunerative.

"The double-headed rails were manifestly intended as a step towards that equalization of the wearing surface, and the sectional area of the rail to which we have alluded, since, in consequence of turning the other side uppermost when the one side has become worn, the difference between the two qualities was halved. It should be mentioned that, however theoretically correct this view of the case may be, it is very doubtful if there is any real economy attending its practical execution. Turned rails are for many reasons very objectionable; it is impossible to properly bed them. The side, once uppermost, presents a surface so uneven and irregular, that on laying it undermost it will not fit into the

chairs which are cast to suit the form of a new and unworn rail, and no amount of wedging or lateral support will compensate for an unsound and uneven bed. The enormous rolling weight of a train *in transitu* will very soon find out the inequalities, and the chances are that the rail will settle down unequally and be forced out of gauge. It is questionable also whether it is advisable to subject the material to strains so violent in a direction totally opposite to that in which it has, perhaps, for some years been acted upon by others of a nature equally severe. Considering the rail as fulfilling that part of its duty common to it and a beam, and supposing it to be laid new, the top is in compression and the bottom in tension. When the rail is turned these conditions are reversed, and the part formerly in tension is now in compression, and *vice versa*. It is needless to point out the danger of this operation, as the plan of subjecting iron to heavy strains of a contrary nature has been amply proved to be attended with very hazardous contingencies. Accidents have occurred through the breaking of double-headed rails which had been previously turned.

“Any inequality in the bedding of a rail might occasion it to be either forced out of gauge, or to deviate from the cast given to it to suit the coning of the wheels. In event of this latter occurring the rail would be subjected to a severe cross strain, which might easily attain at any time to a dangerous amount, and ultimately result in its fracture. As the strength of a beam or girder depends upon that of its weakest part, so the value of a rail is clearly determined by the durability of its smallest part; and when it is eventually removed as unfit for further service it presents an example of the whole being sacrificed for its part. The correct definition of what a rail should be is a beam with an adamantine top or head.

“The chilling the surface exposed to wear and tear, and the employment of steel rails, are both steps in the right direction; and there is undoubted proof, notwithstanding the very limited use of the latter material, that it is in the end more economical than that at present employed. This substitution, it must be borne in mind, is one of degree only, and not of kind, which is what is absolutely required before we can be said to have made any approach to what a rail ought to be. When the head of a

steel rail is worn it will share the same fate as its predecessor, and the whole be sacrificed in a similar manner for the destruction of only a small portion. Compare the case of a rail with that of the cylinder of a steam engine. It will be found that the conditions of our equation are fulfilled with considerably more fidelity in the latter than in the former instance. Again, a cylinder, after having its interior unequally worn by the action of the piston, can be rebores and used a second time, analogously to the turned rails, excepting that the operation is not accompanied with the disadvantages we have pointed out attending the double-headed rails. There is another point to be kept in view respecting the substitution of steel for iron rails, insomuch as it does not carry out the theoretical principles laid down. Granted, that for the present, perhaps for the next ten years or so, they may prove more economical than those they will supersede, yet where is the guarantee that they will not then be virtually in the same condition as our rails are now?

“We must not forget that it is to the increase of the weight of our rolling stock must be attributed this necessity for a more durable description of road. If the weight of our rolling stock were to remain constant—or, in other words, if the causes tending to destroy the rails were not increased in magnitude, then there is no reason to doubt but that the steel rails would maintain their superior qualities of durability and economy. But we are well aware that the very reverse of this will happen. The weight of our rolling stock increases, and will increase, almost daily, and it follows manifestly that a resistance which is adequate to meet its present destructive effects will no longer be competent to do so when those effects are perhaps doubled. The steel rails now coming into use will be as inadequate to meet our future traffic as the new ones are to meet our present.

“That this statement is not merely hypothetical, and based upon no other grounds than what might be afforded by a vague speculation concerning the uncertainty of the future, will be palpable to any one who considers at what a rate the weight of our locomotives have increased. 15 tons, years ago, was considered a very good weight for a locomotive, and we now have them weighing 40 tons and upwards. The truth of our opinions will be considerably more enhanced by the following observations:—

At the present time in France locomotives are running possessing a weight of rather over 50 tons, and M. Houvenot contemplates the construction of others on a still larger scale, reaching the enormous weight of 85 tons. We do not intend at present, taking into consideration what the probable effect upon the rails of a load so enormous would be, as it would involve questions connected with the efficiency of the whole permanent way. We are certain at present that the employment of a heavier rolling stock will necessitate heavier and more durable metals in future, as it has done during the past. The maintenance of the permanent way, in which the rails form the most considerable item, costs four times as much as what it did some thirty years ago. Since a rail has two separate and totally distinct functions to perform, depending upon relative capabilities almost in inverse proportion one to another, it would appear advisable to construct it in a manner which would allow the part so readily destroyed to be removed from the remaining uninjured portion, and to be replaced by a duplicate. It is probable that the forming of a rail in two separate portions, the one to act the part of the beam, and the other to resist the superficial wear and tear, would be accompanied with practical details difficult to surmount. We are not aware that it ever has been tried. Supposing, however, that the practical difficulties were overcome, it is exceedingly doubtful how the rail would behave under traffic. It is not unlikely that the great pressure to which it would be subjected during some years, perhaps might ultimately so amalgamate the two parts that it would be next to impossible to detach them without injury to the sound portion. Again, another difficulty would be experienced with the rails on sharp curves, for, although the two separate parts, say the top and bottom, might be truly bent to any required radius, yet when a new top came to be fixed upon an old bottom, which had undergone for a long period a heavy traffic, it is undeniable that the two would not fit. No matter how accurately a curve may be set out on the line, and however truly rails may be bent to the proper radius, every plate-layer knows that a little 'pulling over' and 'springing' is absolutely indispensable to take the kinks out and make the curve look as it ought to do. It thus appears that independently of the effects of traffic tending to slightly alter the radius of rails on a curve,

it is by no means certain that a duplicate top would always fit the one bottom.

"The time is rapidly approaching when the whole system and construction of our railroads must be entirely remodelled, and it is to be hoped upon sounder and better principles than those adhered to hitherto. There is no portion of a line more important, and bearing more directly for good or evil upon the attendant expenses, than the permanent way, and particularly the rails. In them lies essentially the safety of the trains. Any flaw, unsoundness, defect, or unevenness in them attacks the train in its most vulnerable part, for a very slight impediment is sufficient to throw the wheels off the track; and the contingencies of such an event are not pleasant to contemplate. It is singular that, notwithstanding the prominent part played by the permanent way in the economy and safety of railways, it is the undisguised admission of engineers, that, in comparison with the other branches of railway engineering, it has received the least amount of attention, and is, at the present moment, the worst constituted of all of them to comply with the increasing demands made upon their services."

(b) *The Steel Rail Question.*—"There are few questions," says a writer in "Engineering," "which now possess the same importance to railway engineers and railway companies as that of the substitution of steel for iron rails. It involves not only the broader consideration of the durability of rails, but it embraces also nice questions of the relative strength of steel and iron, of their cost when new, and their value when worn out. On the occasion of the recent discussion of Mr. Price Williams's paper at the Institution of Civil Engineers, the engineering advisers to the railways of the United Kingdom and the Colonies dealt practically and commercially with these questions, and we cannot interpret the result of the discussion otherwise than as a verdict in favour of steel rails, although we are still wanting precise data upon which the extent of their superiority over iron may be definitively pronounced.

"Mr. Williams, in dealing with the question of the life of a rail, endeavoured to bring it as far as possible to that of its mechanical service, and he made the tons moved over a rail the standard of wear, rather than the number of years during which

it might be in use. Two rails, of equally good quality, might be worn out, the one in three years upon one line, and the other in twenty years upon another; the wear following the total weight and the speed of all the trains running over the rail. The former standard approaches precision where that of the service in years does not; but even the tons of traffic borne does not form a precise standard, inasmuch as the wear is related—we will not say in what ratio—to the speed, and to the maximum weights upon a wheel, besides being closely related to the general condition in which the line is maintained, and to that of the rolling stock. Mr. Williams found, from the results of careful observation and record, that good iron rails bore from twelve to fifteen million tons of moderately fast traffic and thirty-eight million tons of slow traffic, while Bessemer rails had borne ninety-five million tons of slow traffic without being nearly worn out on even the single face. It seems to be a notion that rails on down gradients should not wear out as fast as those on up gradients, and thus the question of the pitch and direction of gradients might be considered to enter also into that of wear. But the vertical pressure of a train or a single wheel upon an inclined rail is the same whether the wheel be rolling up or down, and it is the vertical pressure taken in connexion with the total force of motion acting upon the train—or the work stored up in it—that determines the question of wear; and the destructive forces are the same, although the engine force may not be the same, in moving a train down a gradient, along a level, or up a gradient, the speed being supposed the same in each case. By destructive forces we mean the conjoined effects of vertical pressure and advancing motion. The utilised bite of the engine wheels must be harder in going up than in going down a gradient; but it is not certain that the longitudinal force exerted along the rail by what we call the adhesion of the engine produces any sensibly destructive effect at all. In other words, supposing no slipping, it is not certain that any more wear attends the working of a locomotive in the ordinary manner than would attend its motion if towed over the line at the same speed. The friction, or so-called adhesion, whereby locomotives are self-moving, is demonstrably simple static friction, and, so long as there is no slipping of the surfaces in contact, it is not clear that the rails are sensibly injured by

the longitudinal thrust of the driving wheels acting upon them. Mr. Williams has found that, with the same tonnage on ascending and descending gradients of the same pitch on the Great Northern line, the falling rails wear out much the sooner, no doubt because of the greater speed maintained upon them. Thus, on a descending gradient of 1 in 200, between Hatfield and London, the rails are worn out in three years with an average traffic of 12 million tons. On a rising gradient of the same pitch, not far from Peterborough, the same quality of rails lasts six years, and bears 25 million tons.

"The questions of durability and of strength have been decided, and, we may say, without any qualification or deduction, in favour of the steel rail. There were $95\frac{1}{2}$ million tons over the Chalk Farm rail, and the Bessemer rails at and near Crewe Station have borne, in one part of the line, 52 million tons with a wear of only $\frac{5}{16}$ in., and in another $18\frac{1}{2}$ millions with but $\frac{3}{32}$ in. wear.

"As to strength to bear sudden strains and sudden and severe blows, the steel rails are almost beyond comparison with iron rails. Supported upon 5 ft. bearings, steel rails were found by Mr. Kirkaldy to bear in one case over 80,000 lb. applied at the centre, and not one bore less than 25 tons, while the iron rails, tried in the same manner, bore from 36,000 lb. to 50,000 lb. only. Mr. George Berkley has tested steel rails on 3 ft. $7\frac{1}{2}$ in. supports, to a central bending strain of $64\frac{1}{2}$ tons, and he has found the tensile strength of the steel to be from $41\frac{1}{2}$ to $43\frac{1}{2}$ tons per square inch, according as the steel was from the web or the head of the rail.

"As for resistance to impact, Mr. Berkley not long since tested some Bessemer axles, of nearly the same quality as steel rails, with some most extraordinary results. They were railway carriage axles, $3\frac{3}{4}$ in. in diameter, 7 ft. 2 in. long, and were placed upon bearings 3 ft. apart. A falling 'tup,' or ball, weighing 14 cwt. 3 qr., or nearly $\frac{3}{4}$ ton, was then allowed to drop upon them from heights, successively, of 5 ft., 10 ft., 15 ft., 20 ft., and 35 ft. The first axle bore five of these blows, and was deflected 25 in., but there was no appearance of fracture. The second, after two blows of 10 ft. and 15 ft., was then nicked with a cold chisel expressly to break it, the fall then employed being 25 ft.

A third axle, struck with a 14 cwt. ball, bore blows from a height of 11 ft. 6 in., 17 ft., and 23 ft. 6 in., and finally broke with a blow of 36 ft. fall. A fourth was broken by two successive blows from a height of 30 ft. each. A fifth bore five blows, the fall rising progressively to 30 ft., but the axle was not broken. A sixth bore two blows successively, the fall being 10 ft. 6 in., and was then nicked and broken with a fall of 25 ft.

"But axles are not rails, and Messrs. M'Clean and Stileman made some trials of the breaking strength of 73 lb. steel rails and 80 lb. iron rails for the Furness and Midland Railway Company. The rails were keyed in chairs 4 ft. apart, and a 5 cwt. tup or monkey was employed. A fall of 4 ft. produced no set in the steel rail, a fall of 10 ft. gave 1 in. set, and a fall of 20 ft. $2\frac{1}{4}$ in. set only. The rail could not be broken with the means at hand. A second rail took a set of only 1 in. from a 20 ft. fall of the same weight, and a set of $1\frac{1}{2}$ in. from a further blow of 26 ft. fall. This, too, could not be broken. The iron rails, nearly 10 per cent. heavier, broke, the one with a 6 ft. fall of the same weight, the other with an 8 ft. fall. The sets were but trifling, showing, apparently, brittleness of the iron.

"The durability and strength of Bessemer rails being thus proved and conceded, the next questions are those of first cost, interest on cost, and the value of the old material when worn out. If the steel rails last twenty years, where the iron rails last three, then the railway company will lay out of the whole cost of the steel rails for twenty years, where with iron the first cost is not only less, but a considerable sum is recovered at the end of three years towards further renewal. Then, again, it becomes a question whether it is fair, after what has been seen, to compare iron and steel rails of equal weight, and whether compound interest or simple interest is to be considered. It seems reasonable to suppose that the full advantages of steel rails would be had with considerably less weight than is employed with iron. Mr. Hawkshaw has expressed the opinion that the time has arrived when the weights of rails, to bear high speeds, should be increased, and that the weight of steel rails should not be less than 70 lb. or 80 lb. per yard; but this is not opposed to the proposition that steel rails of lighter section than that of iron rails may be employed without sensibly diminishing the greater compara-

tive durability of the former. It will perhaps be more satisfactory, however, to count upon equal weights in both cases, leaving any incidental advantage thereby gained for steel as an additional benefit. Steel rails are made at prices of from £12 10s. to £16, and iron rails cost from £7 to £8, and if guaranteed, as are those made for the Great Northern, £9 per ton. It is doubtful, however, whether really good steel rails can now be had for less than £15, while really good iron rails cost £8 to £8 5s. Mr. Schneider, of Barrow-in-Furness, has publicly stated, however, that first-class Bessemer rails may probably be made to yield a fair profit at £13, and we may perhaps look to this as the future price of steel, under extended competition and for a considerable time to come. We cannot yet say how many iron rails a steel rail may be with certainty depended upon to wear out. But we believe that no competent engineer who has expressed himself upon this subject considers the ratio of durability as less than three to one. In such cases we cannot adopt any precise data, but the general result of the comparison of the first cost, compound interest, and cost of renewal is in favour of steel rails, when these are assumed to wear out each three iron rails. Mr. Johnson, of the Great Northern Railway, has made a careful calculation, the results of which are embodied in a table of much value, showing the cost, year by year, and the total cost for twenty years, of steel and iron rails, at from £12 to £15 per ton for the former and from £7 to £10 per ton for the latter, renewals being allowed for, and compound interest allowed at 5 per cent. on all money as spent. Even this does not show the full value of steel, in the increased safety of the line, and in the lessened disturbance by relaying, &c.; but the results do show that steel may be adopted with confidence, and especially upon all lines where the traffic is great, and the consequent wear of rails rapid. From what Mr. Johnson has said, we cannot doubt that the Great Northern line, which has a few thousand tons of steel rails now in use, will eventually be relaid with them throughout. The Crewe Works are of a capacity to make 300 tons of steel rails a-week, and between 50 and 100 miles of steel rails are already down on the London and North-Western line. Mr. Harrison, of the North-Eastern, is using them in considerable quantities. Mr. Fox, of the Bristol and Exeter, has found

them to be very far more durable than iron rails. Mr. Fowler and Mr. Hawkshaw are using them in their practice; Messrs. M'Clean and Stileman have recommended their use; Mr. Berkley has abundantly shown their great strength; and altogether the judgment of the profession may be said to have been distinctly pronounced in their favour. When worn out, Bessemer steel makes valuable scrap, worth from £7 to £10 per ton. Mr. Schneider, of Barrow-in-Furness, and who, if any one, should know, has stated that the quality of Bessemer metal, as now made, admits of its being cut up, piled, re-heated, and welded with nearly the ease, cheapness, and certainty of iron itself. He finds no difficulty in welding; and the value of worn steel rails may be accepted, therefore, as at least in the same proportion to their original cost as holds good in the case of iron rails."

(c) *Rail Joints*.—"There is no portion of the permanent way of a line of railway which has given more trouble to the engineer than that of the joints of the rails. From the earliest days of steam locomotion it has been a continual source of annoyance and dissatisfaction; and in spite of all the attention and skill bestowed upon it, the problem of making a thoroughly tight and efficient joint is yet to be solved. It is still an undecided question whether the joint should be suspended between the sleepers or rest down upon them. One would be inclined to suppose, judging from the fact that the joints of rails laid upon longitudinal timbers must bear upon the sleepers, that there would be no reason why the same system should not answer best for a road laid on transverse sleepers. A joint suspended between two sleepers is certainly more easy to get at, as a rule, although the absolute advantage of this method depends upon the section of rail employed and the manner in which the joint is formed. Where a bridge rail with an internal fish-plate is used, it would be impossible to tighten up the joint without removing the sleeper it rested upon. Another reason for suspending the joint between transverse sleepers is, that timbers of a smaller scantling can be used than are required in the case where the joint bears on the sleeper. The difficulty of obtaining timber for sleepers of the requisite scantling and proper quality is increasing daily, and is undoubtedly one of the main causes leading to the slow but sure introduction of iron permanent ways. Iron

permanent ways would have superseded wooden roads long ago, but for the fact that not a single one of the former has yet fulfilled the indispensable conditions connected with this branch of railway engineering.

“It is universally admitted that the employment of fish-plates is essential to a good joint in rails. The construction of a rail joint does not in the least differ in its principal features from that of a boiler or girder. The two points to be attended to and carried out are, firstly, that the joint should have the necessary strength, and secondly, that it should be stiff enough. The latter point is the one, as may be readily surmised, which presents the greater difficulty, and in reality has proved hitherto insuperable. That the fish-plates should have nearly the same amount of metal in them as the rail itself is one of the theoretical principles which does not appear to offer any very great difficulty in its practical execution. Nevertheless, this equalization of material is always neglected, and, with barely an exception, there is not a line in which the joints of the rails are sufficiently strong in this respect. When the joint of the rails is suspended, attention to this particular is more necessary than when it rests upon the sleeper. The other, or, it might be said the only obstacle to obtaining a perfect joint, lies in the apparent impossibility of connecting the fish-plates in a manner so as to preserve them completely rigid and immovable under the tremendous shocks they are subjected to. Were these concussions to have any approach to uniformity or regularity of direction, they might possibly be successfully encountered; but they do not even approximate to constancy either in amount or character. A sudden lurch or surging of the engine, the application of the brake, the effect of a curve, and a host of minor contingencies subject the joints of rails to strains of every description. Strains of tension, compression, and torsion succeed one another with a violence and rapidity unparalleled in any other application of wrought iron to the purposes of locomotive traffic. Not only in the case in question, but in every other where two or more pieces of ironwork are connected by bolts, it results as an inevitable accompaniment of this description of attachment, that the nuts work loose when they are subjected to continually recurring vibrations and forces of a concussive and impactive nature. The consequence is that, whenever bolts are used as

described, and submitted to the influences alluded to, there is an incessant process of tightening-up necessary to keep the nuts to their bearings. There is no need of commenting upon the practical interest and importance to the engineer which is afforded by this problem, having for its solution the maintenance of the nuts on the bolts connecting the fish-plates of a rail joint, exposed to the numerous and severe strains resulting from the transit of a locomotive. It is a common practice, and one which is almost self-suggestive, to bore a hole in the bolt and drive in a pin or cotter behind the nut, and so prevent it unscrewing or working loose. This remedy, at first sight, would appear to leave nothing further to be accomplished, but there are several necessary conditions still left unfulfilled. It is quite evident that were the nut screwed home and the pin driven in behind it, nothing could loosen the nut or cause it to unscrew except the pin were first broken short off at the hole. When we consider the enormous strains brought upon the whole joint, and the necessarily limited dimensions of the pin, it is clear that very little reliance can be placed upon this arrangement. It must also be borne in mind that the insertion of the pin very seriously affects the sectional area, and consequently the strength of the bolt itself, which, in its turn, is also liable to fracture. Moreover, it is impossible to bore the hole in the exact place required to cause the pin, when driven in, to come quite home on the bolt, and one or more washers have to be inserted to make up the difference. In a joint the fewer pieces there are the better; every piece of metal more than is absolutely indispensable constitutes a centre of weakness, and helps to endanger the stability of the whole. The majority of fish-plates are connected by bolts having two nuts screwed upon them, as it is considered that the second nut will keep the first one tight and maintain the joint in a sound and rigid condition. That two nuts exert a greater power or resistance to displacement than one does, there is no doubt, but it is simply a question of degree, not kind. They would not work loose so soon or so easily as one would, but the result would be ultimately the same. Arguing on this principle, three nuts would be better than two, and so on *ad infinitum*. The introduction of every additional nut beyond the first, certainly removes the difficulty an additional step, but leaves it in reality in the same state as at the beginning.

“Many other plans have been invented and experimented upon with a view to surmount this serious obstacle towards perfecting our permanent ways, some of which, although sound in theory, cannot be carried out in practice. Others are of so complicated a nature that their manufacture would be attended with a cost unwarrantable under the circumstances. A glance at the position of the joint of a rail and the duties it has to fulfil renders it needless to remark that the means employed to gain the desired result must be both simple in character and cheap in execution. Our rails are now rolled considerably longer than they were some years ago, but, in spite of the increase in the length, an expensive joint is out of the question. One of the best and simplest methods we are acquainted with is that of M. Lucas, a French engineer. He makes the bolt and nut with grooves parallel to their common axis, and when the nut is tightened up so as to make two of these grooves coincide, a longitudinal pin is driven in, and the nut and bolt are keyed on, something after the manner in which a wheel is keyed on an axle. In order to ensure that when the nut is screwed home a groove in the nut should exactly coincide with one in the bolt, the latter has one groove less than the former, and advantage is thus taken of the principle of combinations. The pin is made to taper, and with dimensions a little less than those of the groove it enters, so as to allow of it being readily withdrawn when necessary. The grooves which are not occupied by the key are available in the following manner:—When, after long use, the bolt gets rusty, and it would be nearly impossible to undo the joint without either breaking or damaging the component parts, a little oil can be introduced into the empty grooves, and, by lubricating the parts, allow of the bolt being unscrewed and the joint taken to pieces. This method of M. Lucas has been successfully applied on lines in France—on the Orleans Railway and others. The objection above mentioned relative to the weakening of the bolt by a hole being bored in it is evidently equally applicable to a bolt in which grooves are made. Moreover, it seems that rather a superfluous loss of strength is incurred by employing several grooves where only one is really of any use when the joint is screwed up. If we suppose three grooves in the bolt and four in the nut, when the latter is tightened up there are only two out

of the whole seven doing any work. The other five have simply the effect of materially weakening the bolts which constitute the *point d'appui* of the entire arrangement. We consider, judging from the circumstance that the key is of slightly smaller dimensions than the groove it fits into, that it is quite possible it might become loose by the vibrations it is subject to. It is certain that it would become so by the wear of the neighbouring parts in contact with it. There is no difficulty in tightening it when this event occurs, but, at the same time, there is no difficulty in tightening a nut either; so that, after all, it is not quite apparent whether any real advantage would accrue from the employment of M. Lucas's invention."—*Mechanics' Magazine*.

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION EIGHTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

- The Mont Cenis Railway*,—Engineering, Jan. 5, and Feb. 10, Illustrated.
The Cannon Street Terminus,—Engineering, March 2, p. 141, Illus.
The Manchester Station Roof,—Engineering, Feb. 16, p. 98.
Fish-bars on German Railways,—Engineering, Feb. 23, p. 117, Illus.
Roof of the St. Pancras Station Midland Railway,—Engineering, Jan. 5.
Railway Bridges and Bridge Strains,—Engineering, March 23, p. 192.
The Metropolitan District Railway,—Engineering, Nov. 9, p. 344.
The New Mount Cenis Locomotives,—Engineer, Aug. 31.
Wilson's Locomotive Engine, Indian Branch Railway,—Engineering, Aug. 17, p. 111, Illus.
The Cannon Street Railway Bridge,—Engineering, Feb. 23, p. 116, Illus.
Wrought-iron Wheels,—Engineering, Feb. 23, p. 126, Illus.
The San Paulo Railway Inclines,—Engineering, Feb. 2, p. 70, Illus.
The Penrith Bridge Great Western Railway, Australia,—Engineering, Feb. 2, p. 70, Illus.
Wrought-iron Wheels,—Engineering, Feb. 23, p. 126, Illus.
The Mahavilla Ganga Bridge Ceylon Railway,—Engineer, Oct. 5, p. 250, Illus.
Mansell's Railway Wheels,—Engineer, Aug. 24, p. 132.
Remarkable Locomotives,—Engineering, July 6, p. 1.
Submarine Tunnel from England to France,—Engineering, Aug. 17, p. 118, Illus.
The Mytholme Viaduct,—Engineer, Jan. 26, p. 69.
Bogie Frames for Locomotives,—Mech. Mag., Jan. 12, p. 24.
Gas Apparatus in Lighting Carriages,—Engineer, July 6, p. 10, Illus.
Locomotive Axle Box Guides,—Engineering, July 6, p. 11, Illus.
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- Victoria Bridge, Battersea*,—Engineer, Sep. 7, p. 180, Illus.
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Victoria Bridge—Lon. Chat. and Dov. Railway,—Engineering, Aug. 31, p. 148, Illus.
Swing Bridge over the Penfield at Brest,—Engineering, Aug. 3, p. 82, Illus.
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French Locomotives,—Engineering, Nov. 2, p. 331, Illus.
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Wrought-iron Arched Bridges and Viaducts,—Engineering, May 11.
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Water Crane on the French Railways,—Engineering, April 27, Illus.
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Fell's System of Railways,—Engineering, Aug. 31, p. 162.
Railway Stations and Shops,—Mech. Mag., Feb. 16, p. 107.
Railway Carriages,—Engineering, March 16, p. 165.
On Lighting Railway Carriages with Gas,—Engineer, July 6, p. 7.
Rail and Wheel,—Engineer, Feb. 23, p. 145.

DIVISION NINTH.

SHIPS—IRON-CLAD WAR SHIPS—DOCKS.

SECTION FIRST.—SHIPS IN GENERAL.

74. The great novelty of the year has been the launch of the *Cigar Ship*, of which the following description we take from the 'Engineer:—“A 'cigar ship' is no longer a new thing under the sun. Three have been actually constructed, and launched, and tested, while a fourth—the subject of the present article—is approaching completion as we write. Therefore, we shall not assume that engineers are ignorant of the popularly received notions regarding the principles which these vessels are intended to embody, nor that they are utter strangers to their history and general construction. The idea of forming a ship which should resemble a cigar in shape originated with the Messrs. Winans, American engineers well known in connection with the railway systems of Russia and the United States. To which of the three gentlemen, whether to Mr. Ross, Thomas, or William Winans, the credit of the first idea is due, we shall not stop to consider. The question is of the less importance that all three have entered upon the task of reducing the principle to practice with an energy, skill, and lavish expenditure sufficient to dignify any experiment. Nor is it necessary that we should pretend to pronounce a dogmatical opinion on the merits or demerits of the scheme. We shall best discharge the duty we owe to our readers and to ourselves by reserving all expressions of opinion on matters at present in doubt until they have been advanced a step towards solution by further experiment. Meanwhile we can assure those who take an interest in naval architecture and marine engineering, that the cigar ship scheme constitutes one of the most remarkable experiments on record, and that it has reached such a point that it deserves more attention than it has hitherto received in this country. Although the scheme has been before the world for some seven years—steam being first applied to the propeller of the first yacht on the 7th of January, 1859—it is certain that

very little is accurately known either as to what Messrs. Winans want to do or how they propose to do it. As far as we are aware, the first cigar steamer was a thing *sui generis*, and absolutely novel in principle if not in construction. Naturally enough she constituted a splendid subject for dissertation and discussion, of which people were not slow to avail themselves. On the one hand the thing was praised to the skies, on the other abused to the lowest depths, the greater part of the work, both of praising and abusing, being performed by gentlemen who, to speak plainly, did not know what they wrote about, attributed things to Messrs. Winans which had no existence whatever save in their own imaginations, and made statements regarding the performance of the ships, nearly as exact as the little fancy sketches which were too often accepted by an inquisitive public as a 'correct likeness' of the cigar ship. We shall not exactly attempt to right all these wrongs; but knowing as we do that, notwithstanding page upon page has been written about them, none of the cigar ships yet built have ever been described with sufficient accuracy and at sufficient length to impart a just idea of their actual construction, we propose to correct a few erroneous notions, by explaining exactly what are the very simple objects had in view by Messrs. Winans, and by describing at greater length than has ever yet been done the last and most perfect specimen of the cigar steamer as she now lies in the West India Dock.

"Messrs. Winans have for their object the construction of a ship which shall combine the qualities of speed, safety, economy, and comfort in a pre-eminent degree, and they propose to secure these qualifications by forming a ship as a circular spindle capable of being made water-tight all over, and therefore of behaving in a heavy sea much as a corked bottle behaves, while her great length as compared with her immersed midship section, and the reduced surface which she offers as compared with her capacity, are expected to secure speed. Without entering deeply into abstruse questions of fluid resistance, we may point out that the principal force to be overcome by the engines of a steamer is due to the friction of the water on the immersed surface of the hull. But in the case of vessels built on the ordinary sharp lines, it will be found that this surface bears a very indefinite relation to their powers of flotation. Thus sharp bows, far from supporting them-

selves by their own buoyancy, throw a considerable load on those sections of the hull nearer the stern, and the surface presented by such bows is out of all proportion to the capacity of that part of the hull which they constitute. A keel and the immense surface of dead wood under the stern, also present a large area of resistance, and thus it is claimed for the circular spindle, without keel, dead wood, or bows, that for a given capacity it presents less surface than any other form ever adopted in practical shipbuilding; and this statement is helped out by the well-known fact that the area of a circle is greater than that of any other figure which can be circumscribed by a line of a given length. It is also expected that certain advantages can be gained from the use of propellers of a greater diameter than is admissible under normal arrangements. The consideration of this latter proposition may be postponed for the present. Thus far for speed. Messrs. Winans propose to secure safety by constructing their ship of the best possible form to resist and baffle the action of the waves, and by carrying out the water-tight compartment system to its utmost allowable limit. As the spindle presents no flat places to the impact of the waves, their impulse is always resisted by an arch which tends to break their force by deflecting and dividing their mass; and as the ship has, strictly speaking, no waist, and in hard weather when everything is battened down, no deck openings, seas may break over her without in any way endangering her safety as they would that of an ordinary ship with a flat deck and large hatches near the water. In point of fact, when in hard-weather trim the cigar ship might be submerged several feet below the water for a quarter of an hour without serious inconvenience to those on board. We must, however, correct the mistaken impression which is generally entertained, that the ship is intended to pierce the waves instead of riding over them; nothing can be further from the thoughts of her builders. That she will pierce a wave now and then is a species of accidental concomitant of her shape, but it is not intended that she should do so, and it is hoped that she will ride over waves instead of passing through them. On encountering a wave of more than ordinary height her sharp bow will enter it no doubt, but as the bow proceeds its powers of flotation are called into play, and hence the moment its displacement exceeds its load it will rise, the water tumbling

off to either side much as the earth falls away from the plough-share. It is possible that the idea that the ship is specially intended to pierce the waves, and in fact spend much of her time under water, has done more to draw down unmerited ridicule on the scheme than any other point connected with it. The upper portion of the hull is only intended to act the part of the hurricane deck, which all sharp and fast steamers—such as the Holyhead mail-boats—must carry as a necessity. And it is just as reasonable to suppose that the Leinster or Ulster are specially designed to drive through the waves as that the cigar ship is. As to comfort, it is known that one of the most serious discomforts to which a crew can be exposed is caused by the intrusion of water below. Now so long as the cigar ship remains whole, water cannot find its way below when it is necessary to keep it out, any more than it can get inside a duck or a gull. But it is obvious that this advantage cannot be secured unless extraordinary pains are taken to provide ventilation. We shall see presently what steps Messrs. Winans have taken to secure this point. It thus becomes evident that the ship is designed to behave in a sea much as does a Mother Cary's chicken, or to use our first simile, a corked bottle, and it is well known that both set the waves and the wind at defiance by yielding to them. Even an Atlantic gale is gentle as a zephyr so long as nothing opposes its fury; and its powers of mischief are reduced just in the same ratio as the opposition.

“We have stated that the present is the fourth ship built by Messrs. Winans on the ‘cigar’ principle. The first, launched at Baltimore in the latter part of 1858, was 235 ft. long; the maximum diameter of the hull being 16 ft. This vessel resembled two sugar-loaves placed base to base, and connected by a peculiar arrangement. The hull practically consisted of two portions, identical in every respect. The bulkheads which answered to the flat bases of the sugar-loaves being placed within a few feet of each other, left a space between, within which rotated a propeller 25 ft. 4 in. in diameter. In order to connect the two sections of the hull, a sleeve was employed surrounding the propeller, 25 ft. 6 in. in diameter inside, and 10 ft. or 12 ft. long. This sleeve was affixed to the fore and aft sections of the hull by strong gusset-shaped stays of plate iron, disposed in the

plane of the axis of the ship. The propeller, projecting beyond the hull, was thus half submerged, and remained absolutely unaffected whether the ship pitched or rolled. Its submersion was always the same, and the engines never manifested the slightest tendency to race in the heaviest sea. With this vessel many experiments were conducted. It is said that she attained a speed of $17\frac{1}{4}$ miles per hour with extraordinary economy of power, and upon the whole her builders considered that the results obtained demonstrated the success of the principle with which their names are now identified. But she was very far indeed from that perfection which her builders hoped to reach ultimately. She therefore underwent numerous alterations, but the grand defect was too radical in its character to permit of mitigation. The fractional resistance of the submerged portions of the sleeve was enormous, and the entire arrangement was deficient in that strength which was required to render the ship pre-eminently seaworthy. After a time it was decided to begin *de novo*, and a cigar ship or rather boat, 70 ft. long and 9 ft. diameter, was launched some months since at St. Petersburg, Russia. This boat was fitted with a single small propeller beneath her bottom, and therefore wholly submerged. The vessel was roughly got up for experimental purposes, the propeller being driven by an old portable engine, yet we understand that she ran off 9 knots per hour—a remarkable result if we consider the conditions under which it was obtained. The position of the propeller in this case was nearly as unsatisfactory as it could well be, since it added enormously to the boat's draught, and was constantly exposed to damage in shallow water. A third boat was then built at Havre, by MM. Nilus and Son, and launched about a month since. This boat very much resembles that built at St. Petersburg, being approximately of the same general dimensions—72 ft. by 9 ft. and 33·4 tons burthen, but she is fitted with arrangements for trying the ordinary propeller wholly submerged, or a semi-submerged propeller, or four submerged propellers arranged on what we may term the quarters of the vessel. She has a double-cylinder high-pressure engine, driving, by the aid of gearing, a number of distinct shafts passing through tubes and stuffing-boxes projecting from the hull, and to any one or all of these shafts, propellers may be affixed and driven together or separately by

the gearing, at pleasure. The boiler is of peculiar construction, resembling those which have been adopted in Messrs. Winans' last yacht, to which we have now fairly come.

This vessel was commenced nearly two years since by Mr. Hepworth of the Isle of Dogs. After she had made some progress, however, Messrs. Winans deemed it best to complete her themselves, and for that purpose they made the necessary arrangements with Mr. Hepworth for the use of his yard and plant. Nothing can so effectually dispel preconceived notions regarding Messrs. Winans' theory as the actual inspection of this vessel. Every facility for this purpose has been courteously placed at our disposal by her builders, and we have been through her, as she lay on the stocks, from end to end. We have examined her from the stuffing-boxes at either end—only to be reached by crawling snake-like through small ports in the water-tight bulkheads, along the little gangway which covers her shaft—to her sumptuously fitted saloons and state rooms. Our readers possibly imagine a damp, crank, dangerous, unsightly craft; on board which nothing but a keen love of science would induce a man to risk his life. We may just whisper the confession that the opinions we held were something very like this. Yet would we have all men banish such ideas at once and for ever. The Winans' yacht is as strong, perhaps as it is possible to make a vessel; before we have done, our readers will have an opportunity of judging of the merits of the precautions taken to avoid risk of foundering; and her saloons and state rooms exceed in comfort those of any ship of her displacement—500 tons—whose decks we have ever trod. A fact due no doubt in some degree to their height. Thus the clear head-way in the main saloon is 10 ft., and this advantage is also extended to the state rooms, where every inch of space has been economized so skilfully that more of it would be apparently superfluous.

"The hull is 256 ft. long from point to point, and 16 ft. in diameter. Her launching draught with engines, boilers, &c., on board will be 8 ft., while her stores and ten days' coal—175 tons—will take her down about 30 in. deeper. In form she is a circular spindle, tapering each way from the centre. No portion of the hull is a true cylinder, and the form actually given to it has been only adopted by the builders of the yacht after a long course of

experiments by trial and error had demonstrated that it gave a minimum of resistance. The lower portion of the hull is composed of $\frac{5}{8}$ in. plates of the very best iron ever used in shipbuilding. The upper half of $\frac{5}{16}$ in. steel plates from John Brown and Co. She is perfectly flush outside, being double and treble rivetted throughout. The joint straps are all of great breadth, chain rivetted where any longitudinal strains have to be resisted. In this respect the workmanship is simply faultless. The hull proper is 224 ft. long, and 4 ft. diameter at the extreme ends, which consist of cast iron discs of great strength, with heavy return flanges. These flanges are placed within the open ends of the wrought iron tube and carefully rivetted in with three rows of rivets, the plates being then caulked down on the cast iron outside. In the centre of each disc is formed a stuffing-box of somewhat peculiar construction, through which passes the screw shaft of Krupp's steel; in this place 15 in. in diameter. The weight of the shaft and propeller is supported by rings of lignum vitæ, arranged within the stuffing-box. Immediately outside the cast iron terminals of the hull come the screw bosses of the same diameter at the inner face, but following the proper circular curve in the direction of their length. The forward faces of these bosses carry cones of plate iron, making with the boss a length of 16 ft. and rotating with the screw. These cones conform in outline to the curve of the rest of the ship even down to the little steel spikes which render the ship literally as sharp as a needle, and by their buoyancy they do something to reduce the weight to be supported by the stuffing-boxes. We shall postpone the consideration of the propellers for the present. We have thus each end of the ship terminated by a blunt surface, 4 ft. in diameter—the transverse section of the spindle or hull—and revolving in close proximity with these, the screw bosses, each 4 ft. in diameter and a couple of feet long, to which are attached the two portions which we may suppose to have been removed to get a section 4 ft. in diameter, these portions revolving with the screw. It will be seen that this arrangement is after all merely a modification of that adopted in the first ship. In her, let us suppose that the after end only, contained the machinery, &c., while—the sleeve being suppressed—the forward section was attached to, and revolved with, the screw boss. We should then

have arrangement differing in nothing from that actually adopted in the present yacht, but in the relative proportions of the revolving and stationary sections of the hull; and we have no reason to doubt that this arrangement is the best which could possibly be adopted under the given conditions.

“The hull is strengthened and stiffened, first by thirteen transverse bulkheads of stout steel plates; secondly, by the decks, also of steel, one before and the other abaft the engine-room, giving, in all, including the bunkers, twenty-one water-tight compartments; thirdly, by the engine-frames, which tie her together vertically, floor and upper deck; and lastly, by rings of angle and bulb iron disposed at frequent intervals. Before going further, it may be well to give a general idea of the arrangement of these bulkheads and decks. The first compartment forward contains the rudder-head and its gear, to which we shall come presently, and the screw shaft. As the hull is little over 4 ft. diameter here, there is of course no deck. The second compartment is also without a deck, but being more roomy, the screw-shaft is here boxed up, and the surrounding space is employed for the stowage of stores of various kinds. The fourth compartment forward is provided with a deck put in about 20 in. below the centre of the ship, and fitted up with sleeping berths for fourteen men and boys. It is set apart for the firemen and coal trimmers. Next to this comes a fore saloon or smoking-room about 15 ft. long and 11 ft. wide; next to this, state-rooms for captain and officers. Then the boiler room divided from the engine-room by a bulkhead. Still travelling aft we come next to the main saloon, a beautiful apartment some 25 ft. by 15 ft. Next to this are state rooms. Then a cabin for the crew, with berths for eight or ten, part of the room being taken up by the anchor windlass. In other respects this compartment answers to that provided forward for the stokers. Behind this again is a compartment without a deck for stores, and aft of that again the last compartment containing a second rudder-head—for the ship has two—the screw-shaft and stuffing-box. All these compartments are provided with heavy metallic doors shutting on india-rubber. The doorways in the first two bulkheads forward and aft are only large enough to suffer a man to creep through, but the others, at the feet of the companions are nearly 6 ft. high,

with semi-circular heads. These doors are of steel plates set in a heavy brass framing, so painted as to resemble bird's-eye maple mouldings. The brass rings are fitted with pointed set screws acting like ordinary shot-bolts, which when the door is closed pass behind suitable plates on the bulkheads, and by the wedge-like action of their points draw the doors home, water-tight, against india-rubber strips provided for the purpose. The decks are tied down to the floor of the ship by stout stays to prevent them from being blown up by the confined air should the ship spring a large leak below. As there is no direct communication with the compartments beneath what, we suppose, we must term the main deck, they can only be reached from the upper deck. They are solely devoted to the stowage of coal. It will thus be understood that each inhabited compartment is provided with a deck that may be termed the main deck, beneath which coal is carried. Although this arrangement is exceedingly conducive to safety, it is thus far inconvenient that after the boiler-room bunkers are exhausted, all the coal must be conveyed some little distance along the upper deck to the boiler-room bunkers, after having been hoisted in buckets through tubes or shoots by light whips rigged on the masts.

"It is now time to turn our attention to the upper deck. This is a platform 10 ft. 6 in. wide amidships and 130 ft. long, constructed over the central portion of the length of the hull. It consists of two walls of plate iron rising from and rivetted to, but forming no integral portion of the hull. These are of such a height, that the deck just rests on their upper edges and the highest point of the circular upper portion of the hull; spandrils being left at either side, between the walls, the deck, and the skin, containing ventilating trunks about which we shall have something more to say. This deck tapers off to each end, and is surrounded by vertical bulwarks about 2 ft. 6 in. high, and a wire running line supported by polished brass standards. At the forward end these bulwarks terminate in a species of bow, like that of an ordinary steamer, carrying a beautifully carved and gilded American eagle as a figurehead; at the after end is a simple shield. Standing in, or rather on these bows, the black hull, stretching away nearly 65 ft. in advance, appeared very remarkable, even as the vessel lay on the stocks, and will no doubt

appear still more so when rising and falling on the waves, now lifting its length clear above the swell, and anon partially burying itself in the foaming wake of the leading propeller like a porpoise reluctant to leave the surface. It has been said that the yacht would lie like a log, as a toy for the sport of the waves, should any casualty occur to her machinery. The statement has no foundation in fact; amidships are two short though graceful funnels, and forward and aft on the upper deck are two telescopic masts, capable of spreading a very considerable expanse of canvas—quite as much indeed in proportion as is usually carried by paddle-wheel steamers. The lower portions of these masts are made of boiler plate, terminated above by cast-iron cup-shaped capitals, thus far resembling small subsidiary funnels, for which indeed we believe they have more than once been mistaken. Each cup serves to conceal two small cast-iron rollers over which run a pair of light but strong chains. The ends of these are attached to the heel of a stout wrought-iron hollow spar—the top-mast in fact. When struck this spar descends within the lower mast, taking the chains down with it. In order to raise the top-mast it is only necessary to haul on the chains. These running over the rollers elevate the mast to the proper height, and being properly secured form shrouds for the lower mast. The arrangement is simple and elegant. All the canvas carried will be ‘fore and aft.’ The deck is provided at either end with a cook house and steward’s pantry, from which companions descend into the compartments set aside as cabins for the crew and stokers, the companions to the fore and aft saloons also open on this deck of course, and are provided with somewhat unusual expedients for keeping out water. So far we have placed before our readers something more than a general description of the construction and arrangements of the hull of this remarkable yacht. The consideration of her machinery, fittings, &c., we must reserve for another paper.”

75. *Propulsion of Vessels by Jets.*—In the “Engineer” the following article is given, taking up several of the points involved in the theory and practice of propulsion by jets, having direct reference to the trials of two vessels which have been recently launched on this principle, namely, the ‘Nautilus’ and the ‘Waterwitch.’ “The success which in many respects has attended

recent trials of Ruthven's jet propeller has drawn the public attention to that form of apparatus for driving vessels. Some misconception is likely to be caused by the application of the term 'reaction' to the mode of working of the jet propeller exclusively, as if the reaction of the water were peculiar to it, as distinguished from other forms of propelling apparatus. The truth is, that all propellers, whether oars, paddles, screws, jets, or of any other conceivable kind, work by means of the reaction of the water which they drive astern, and that the differences between them are merely matters of detail.

"One rule, deduced from the second law of motion, serves to compute the reactive force exerted upon the ship by any propelling apparatus whatsoever. The apparatus operates upon a certain number of pounds of water in each second. The water so operated upon, when first laid hold of by the propelling apparatus, may have been still, or it may have been moving ahead, as the water at the stern of a steamer moves before being acted on by the screw, or it may have been moving astern, as the water alongside of a vessel moves at one period of its motion. In any case the propelling apparatus impresses a sternward velocity upon each of those pounds of water upon which it operates, and that sternward velocity is combined with the velocity, if any, which the water had before being operated upon by the propelling apparatus. The result is, that a backward pressure is exerted by the propelling apparatus upon the water so operated upon, and that an equal and opposite forward pressure is exerted by that water upon the propelling apparatus, and transmitted by that apparatus to the ship. The amount of such pressure is calculated as follows:— Multiply the number of pounds of water operated upon in one second by the sternward velocity, in feet per second, impressed on that water by the propelling apparatus; divide the product by the number of feet per second of velocity produced by the force of gravity in a second; the quotient will be the required pressure in pounds; that is, the *thrust* of the propeller.

"The total thrust given by the preceding calculation may in some cases require a deduction to be made from it, if there is anything in the action of the propelling apparatus tending to increase the resistance of the vessel; for example, when a screw, working under the stern of a ship that has a bluff after-body,

diminishes the pressure exerted by the water on the run of the ship, and so increases the excess of the pressure against the bow above the pressure against the stern.

"The intermediate processes undergone by the water ; for example, the fact that in Ruthven's apparatus, the water is in the first instance drawn into and carried along with the ship, before being finally driven astern, may affect the resistance of the propelling apparatus, but cannot alter the thrust obtained, which depends on the total change of velocity impressed on the water, and not on the steps by which that change takes place.

"In starting a ship from a state of rest, the thrust of the propeller is at first greater than the resistance of the water to the motion of the ship ; and the velocity of the ship, therefore, increases until those two opposite forces become equal ; and then she goes on with an uniform speed. When that state of things has been attained, the useful work done in foot-pounds per second is the product of the resistance of the vessel in pounds by her speed in feet per second. The total work done is made up of the useful work and the lost work. In the lost work are included all quantities of work done in impressing vertical motions on the water, as in the paddle-wheel, or transverse motions, as in the screw ; for such motions give rise to no forward reaction. Those parts of the lost work are capable of great diminution by means of such contrivances as the feathering paddle ; and in the jet propeller they may probably be regarded as insensible.

"Another cause of loss of work is the friction of the propelling apparatus, whether consisting in friction between it and the water upon which it operates, or between the solid pieces of which its mechanism consists.

"There remains to be considered a part of the loss of work which occurs in every kind of propelling apparatus, and which cannot by any human ingenuity be diminished below a certain limit, and that is the work expended in impressing backward velocity on the water through whose forward reaction the vessel is propelled. The amount of the work so lost in foot-pounds per second is the product of the thrust of the propelling apparatus (equal and opposite to the resistance of the vessel) into the backward velocity in feet per second impressed on the water operated upon, or *true slip* ; and the proportion which it bears to the

useful work is obviously equal to the proportion borne by the true slip to the speed of the vessel; that is to say,

$$\frac{\text{work lost through true slip}}{\text{useful work}} = \frac{\text{true slip}}{\text{speed of vessel}}$$

“To diminish, then, the loss of work from this cause, there is but one way, and that is to diminish the true slip. And because the thrust of the propeller (equal and opposite to the resistance of the vessel) is equal to the true slip multiplied by the weight of water acted upon in one second by the propelling apparatus, it is evident that there is but one way of diminishing the true slip, and that is to increase as much as practicable the weight of water per second operated upon by the propelling apparatus. If these principles be put in the shape of an equation, they take the following form:—

$$\begin{aligned} \text{True slip} &= \frac{\text{resistance} \times \text{gravity}}{\text{weight of water acted on per second}}; \quad \text{and} \\ \text{therefore, } \frac{\text{work lost through true slip}}{\text{useful work}} &= \frac{\text{resistance} \times \text{gravity}}{\text{weight of water acted on per second} \times \text{speed of vessel}}; \end{aligned}$$

the speed being expressed in feet per second.

“The weight of water acted upon per second depends mainly on the sectional area of the race or stream of water operated upon, and hence the well-known fact that to make that area as large as practicable consistently with the dimensions and form of the vessel, is favourable to economy of power.

“If we now compare together the various forms of propelling apparatus with a view to their economy of power, as inferred from the principles before stated, the following conclusions are obvious:—

I. As regards loss of work through friction of the propelling apparatus, direct experiment alone can be relied on; but there is no reason to believe that there can be any very great difference between the jet, the paddle, and the screw.

II. As regards loss of work through impressing vertical and transverse movements on the water, the jet must obviously have the advantage over both the screw and the paddle, for it sends the whole stream of water directly astern; though the advantage over the feathering paddle is probably not very great.

III. On the other hand, as regards loss of work through true slip, the jet, as hitherto used in practice, is inferior both to the screw and to the paddle, because of the comparative smallness of the area of the stream which it drives astern, and consequently of the weight of water operated upon by it in each second.

"This last conclusion is confirmed by every fully-reported experiment on propulsion by the jet. For example, in the case of the steamer Nautilus, driven by the jet propeller at a speed of 8.3 knots nearly; the length of the vessel is 115 ft., the breadth 15 ft., and the draught of water 2 ft. With feathering paddles, each pair of float-boards having an area of from 8 to 10 square feet, a very liberal estimate of the indicated power required to drive that vessel at the speed mentioned would be from 55 to 60 horses. Her jet nozzles have an area of only 1.4 square foot; and the indicated power actually expended in driving her is reported to have been between 90 and 100 horses. Let us next take the Waterwitch, 162 ft. long, 32 ft. broad, drawing between 9 ft. and 10 ft. of water, and driven at 8.9 knots. A pair of paddles for such a vessel would have a combined area of 30 or 35 square feet, and the screw would have a disc area of between 60 and 70 square feet; and the indicated power required to drive her at the given speed by paddles or screw would be between 250 and 300 horses. The combined area of her two jet nozzles is 6 square feet, and the indicated power expended during her late trial is reported to have been about 700.

"In both vessels the surface speed of the pump wheel was double the speed of the vessel.

"It is evident, therefore, that the experimental trials of vessels propelled by jets show losses of power corresponding to the smallness of the area of the streams of water operated upon; and hence that propulsion by jets, as hitherto tried, is by no means an economical method of using power.

"Nevertheless, the convenience of the jet for manœuvring, especially in the form devised by Messrs. Ruthven, and the ease with which it can be completely protected against shot, constitute undoubted advantages, and there may be circumstances in which these may outweigh the comparatively great expenditure of power.

"The following is a calculation of the resistance of the Waterwitch, and useful work of driving her at 8.9 knots, based on the

reported approximate data as to the quantity of water operated upon by the propelling apparatus:—

Area of nozzles, square feet,	6
× Velocity of discharge of jets relatively to the vessel, feet per second,	30
Volume of water operated upon in a second, cubic feet,	180
× Weight of a cubic foot of sea water, lb.,	64
Weight of water operated upon in a second, lb.,	11,520
Final sternward velocity impressed on that water = velocity of jet — speed of vessel = (in feet per second) 30 — 15 =	15
Divide by $g = 32.2$,	)172800 product
Probable resistance, lb.,	
× Speed of vessel, feet per second,	15
Useful work, foot-pounds per second,	80,490
$80,490 \div 550 = 146.3$ effective horse-power.	

“The power expended in driving the water astern is the same, viz., 146.3-horse power; making a total of 292.6 horse power expended in driving the water astern, and the ship ahead, exclusive of that lost in overcoming the resistances of the engine and pump.”

76. *On the Safety and Seaworthiness of Vessels.*—A paper by Mr. John Ferguson was read before the Institute of Engineers for Scotland under the above title, of which we give the most important portion:—“Recent events have excited an unusual amount of interest about, and inquiry into, the safety and seaworthiness of vessels, and it may be well for an Institution such as this to give an expression of their opinion, as to whether any course might be adopted which would insure greater safety to our mercantile navy, either in their build, equipment, or management. It is a fact that every year there is a great number of losses among the vessels belonging to or trading to and from this country. I am not aware that the losses are increasing in a greater ratio than the increase of shipping; still, from the greater supervision which vessels are subject to, and the improvements which are taking place in their construction and outfit, together with the application of steamers to nearly all our maritime commerce, we should expect that the casualties would be decreasing.

“The foundering of the *London* and *Amalia*, and the immense loss of life and property on our coasts during this winter, together

with the inquiries instituted by the Board of Trade into the causes of the loss, especially regarding the two above-named vessels, has brought out many suggestions and opinions as to how accidents to the same class of vessels in like circumstances might be prevented, besides indicating what were the immediate causes of the destruction of these vessels. All our members must have read with painful interest the particulars given in the newspapers of the investigations as to the loss of these vessels—vessels which we have every reason to believe were strong and faithfully built and well equipped, able to stand the severe buffetings they were subject to without straining, and yet they had to succumb to what we might call trifling defects in their deck arrangements. From such events we have much to learn; and if we have arrived at the true causes of these catastrophes, it is a duty which devolves on us to discuss the subject, to see whether any remedy may be found which might tend to prevent the recurrence of such accidents. And I would notice, that it is evident from the reports that the foundering of both these vessels was preceded and accelerated by the immense body of water which was shipped on deck. In the case of the London, the lower part of the ports for taking water off the deck was about 16 inches above the top of the deck, in consequence of there being a box waterway or spir-ketting which extended up to that height, so that, until the decks were filled with water up to the top of that spirketting, it had no way of getting off except by the scuppers, and if these were filled up by the coals washing about the deck, then we can understand what difficulties the crew had in their endeavours to close up the engine-hatch after the skylight was washed away, especially when we are informed that the coaming of the engine-hatch was only about 11 inches above the deck to the check, thus showing that the water on deck would be flush with the top of the permanent coaming before it could get egress by the side ports, even if the ship was lying level. The quantity of water the deck would contain below the level of the ports would probably exceed 100 tons, and this weight would be increased more than fourfold when the water would be up to the main rail. It can easily be imagined that such a weight thrown on the top of a ship would tend to make her unmanageable, besides the risk of the water breaking into the holds or engine-room through any of the deck

openings, or into the poop or deck-houses, while to aggravate the evil, it would prevent the crew from doing anything to mend matters by pumping or stopping the openings on deck. Ship-builders and owners are aware of such results being likely to follow the carrying of a large body of water on deck, and hence in vessels intended for stormy passages provision is made for lessening the evil by having high coamings of iron at the engine-hatches, inclosed stock-hole gratings, and in some cases the front of the poops are made of iron, besides having the ports in bulwark as low as possible. Various suggestions have been made to remedy the evils complained of, such as raising the engine-hatch coamings, deck pumps, and sounding-rod tubes to a considerable distance above the deck; and some people are of opinion that the great length of steamers in proportion to their breadth causes them to be less seaworthy than if they were broader or shorter. It may be an evil to make vessels of extreme proportions of length to breadth, inasmuch as that the weight of the upper part of the vessel is increased by the additional strength required; but I am not aware that vessels built of iron, of the usual proportions and construction, are more liable to foundering than shorter vessels.

“If we are correct in our inferences, drawn from the reports of the loss of the *London* and *Amalia*, viz., that their destruction was accelerated by the masses of water which they took in on deck, we would naturally conclude that if vessels were so constructed as to be free from the liability to retain water on deck, then they would be free from the liability to founder under similar circumstances. It is the opinion of many that if our large steamers, which have to sail in all weathers, had spar-decks, the evil of having the main decks filled with water would be overcome, as in vessels of that construction the water could have no lodgment on the upper deck; and as prevention is always better than cure, it surely must be safer to keep the body of water off the top of the vessel than to have it remaining on, especially when its presence is attended at times with such disastrous consequences. It may be unnecessary to describe the points of difference between a spar-deck ship and one with an ordinary main deck, further than to state that most of our large steamers which carry passengers, and have no spar-deck, have poop and fore-

castle, or deck-houses, amidships, all above the main deck; some have poop, forecastle, and deck-houses arranged so that the vessel is nearly all covered in, excepting in the part between the poop and the forecastle, bounded by the bulwarks on the one side and the deck-houses on the other. This open space is where any body of water which breaks on board lodges, and where in being confined it is so injurious. In such ships the crew are accommodated generally under the topgallant forecastle, and the officers in the midship deck-houses. In spar-decked ships the arrangement of the forecastle, officers' rooms, cabins, &c., may be precisely the same as just described, but the entire upper part of the ship is covered in, the side of the vessel being carried up to the upper beams. The spar-deck is generally surrounded with an iron railing and staunchions instead of the high close bulwarks required for the other description of vessel. The fact of the spar-deck being seven to eight feet above the main deck, shows that the sea would have to rise that additional height before it could get above the vessel; and even should it get on the spar-deck, there are no barriers to prevent it getting off at once without the same risk of doing damage by breaking into poop, engine-room, coal-hatches, &c., owing to the deck openings being so much above the load line, which in all cases should be regulated by the main deck. I believe that the principal barrier to the adoption of spar-decks for our large passenger steamers is, that being built in that style, they rate much higher in their tonnage than vessels with the same accommodation which have the poops, forecastle, and deck-houses. In the latter class of vessels, the tonnage of the space occupied by the crew is not included in the tonnage of the vessel, unless it exceed one-twentieth of the gross tonnage, when the excess is included in the tonnage; while in ships with spar-decks the space occupied by the crew is included in the tonnage, although the arrangement on the main deck may be precisely the same in both cases. It seems an anomaly that such should be the case, as it is manifestly unfair.

“The overloading of vessels is another subject which has lately been brought prominently before the public, and it seems to have been under the consideration of the Board of Trade, as to whether they should exercise any control over the loading of vessels, as

reported in the newspapers. Mr. Milner Gibson, President of the Board of Trade, in reply to a question put to him in the House of Commons, said—‘In consequence of the reports on the loss of the London and Amalia, the question whether the deep sea line could be permanently marked on all vessels carrying passengers and merchandise, had been considered by the Board of Trade, but the difficulties were found to be insuperable, the Government officials having no means of marking the deep water line applicable to all circumstances, or of deciding how deeply a vessel may with safety be immersed in the water.’

“There is no doubt but there may be difficulties in the way of determining the depth to which vessels should be loaded; but if it is a fact that the loss of many a vessel may be traced to overloading, it is surely worthy of an effort being made to arrive at what would be a fair depth to which vessels might be loaded. The underwriters recommend that ships should have three inches of side from the top of the deck to the deep load line for every foot of depth in hold; but we fear that in many cases such a recommendation has no weight or authority.

“In steamers, which carry a large quantity of fuel for long voyages, and which by the consumption of fuel are getting lighter every day, it is not so easy to define the depth at which they should leave port. But surely our steamship owners could give sufficient data as to what has proved to be safe immersions. This, with the information from other sources, might decide on the depth to which vessels could be safely loaded according to the season of the year. It might be a question for our consideration whether the draft should be regulated by the depth of hold amidships, or whether the sheer or height forward and aft should be taken along with the midship depth, or in vessels with a great breadth in proportion to their depth perhaps the breadth ought to form an element in determining the deep load line. There may be some other elements to be taken into account, and I believe that if we could suggest any reasonable proposal to the Board of Trade it would receive their favourable consideration.

“In reference to the large number of wrecks which have taken place on our coasts during the past winter, they were nearly all sailing vessels driven on shore by stress of weather. And we see that steps are being taken for the erection of a lighthouse at a

part of our Western Islands where it cannot fail to be of service to vessels driven towards that dangerous coast. I think also that the erection of a breakwater in Lochindaul, Islay, would be the means of giving shelter to many vessels which are obliged to try for shelter among the islands, when they cannot manage to get through the North Channel. Lochindaul seems to be a natural harbour of refuge, although at present it is not safe, owing to the want of some artificial shelter.

“There are many cases of shipwreck or foundering through a variety of causes which it is not easy to foresee or provide against, but it is a duty which devolves on all connected with shipping to remedy defects wherever they are known to exist; and I hope the members of this institution will give the subject their best consideration.”

77. (a) *Security of Iron Ships.*—(b) *Balanced Rudders for Screw Steamers.*—A paper on the first of these subjects was read before the Institution of Naval Architects by Mr. William Fairbairn, LL.D., F.R.S., and on the second by Professor Rankine; abstracts of these, as given by “Engineering,” we here append:—
(a). *Security of Iron Ships.*—“In this communication it would not be without interest to endeavour to show the advantages and disadvantages of the leading features of high speed constructions, and to exhibit the differences which should exist between a vessel intended for the navigation of smooth water, and another that had to contend with the rolling seas of the Atlantic.

“For the first class of vessels it was necessary to have great lengths, narrow beams, and diminished depths; for the second, it was important that these dimensions should be altered in order to meet all the contingencies of strain in a rough sea. For example, if we took a vessel 320 ft. long, 40 ft. beam, and 26 ft. deep, we arrive at the following proportions of eight times the beam and twelve times the depth for the length. Now, a vessel of this construction, with fine lines, was admirably adapted for speed, whether propelled by wind or steam, but her security was doubtful, if heavily laden, when subjected to pitching and rolling in a tempestuous sea. A vessel of this description would be wet and most uncomfortable, and her want of buoyancy at the stem and stern would cause her to bury her bows to a considerable depth when pitching, and sweep her decks with tons of

water as she rises to the surface. But this was not all, as at every plunge the ship laboured heavily, and suffered severe strains by the weight of water she had to lift in ascending from the middle to the crest of the wave. In every case of high speed in smooth water these proportions and fine lines were highly advantageous; but in those intended for long sea voyages, it was questionable whether or not some slight sacrifices should be made as regards speed, and some modifications effected in the build, in order to meet all the requirements of a safe and convenient vessel, intended for the double purpose of accommodating both passengers and cargo.

“In this communication it would not be necessary to enter upon the calculations of resistance to strains in such vessel. The object was to show that they are in actual existence; and some, from their slight build and great length, had comparatively but a small margin of strength, and were therefore not trustworthy in cases of a heavy cargo and foul weather at sea. To render vessels perfectly seaworthy, the author would recommend that their lengths should never exceed seven times the breadth of beam and ten times the depth. In these proportions he was assuming that the ship was strong and substantially built, and that in the place of the lines of least resistance being observed at the bows and stern, that additional buoyancy should be given, in order to enable the ship to rise freely on the sea, and by increased displacement the discomfort of the sea sweeping the decks would, to a great extent, be avoided.

“It was some years since the author endeavoured to impress upon the minds of naval architects and builders the necessity of increased strength in the hulls and upper decks of iron ships, in order to balance the two forces of tension and compression. He also pointed out the advantages to be derived from the longitudinal keelsons, cellular principle of construction, water-tight bulkheads, and double bottoms; and when we considered that the strength of a vessel is the maximum resistance of its weakest part, it followed that any increase of material where it was not required was the very reverse of useful, and never failed to prove injurious. In every structure subjected to strain, it was desirable that uniformity of strength and the laws of proportion should be strictly observed, and the author thought that a close adher-

ence to sound principles of construction in iron shipbuilding would not only mitigate the evils of which we complain, but would ultimately lead to increased efficiency and an important saving of the lives and property of the country."

(b) *Balanced Rudder for Screw Steamers*.—"It was well known that Mr. Arthur Rigg has proposed to use fixed deflecting blades, for receiving the current of water driven obliquely upwards by paddles, and obliquely in various directions by the screw, and turning that current into a direction right aft; in order that the increased pressure on the concave surfaces of such blades, and the diminished pressure on their convex surfaces, might produce an additional thrust for driving the vessel, and thus save power which would otherwise be wasted. That invention was correct in principle; and from the reports of recent experiments, it appeared to be likely to succeed in practice as applied to the screw.

"Considering that fixed deflection blades were applicable only to vessels which have an after sternpost abaft the screw, and not to those which have a balanced rudder and no after sternpost, Mr. James R. Napier and the author of this paper had proposed to make the balanced rudder itself deflect the water gradually into a right aft direction, by so shaping it that, when the helm is amidships, the forward edge of the rudder should stand tangentially to the current coming from the screw, and that its after edge should point right aft.

"It was observed, that the ordinary plane rudder, when standing amidships, deflected the stream of water* from the screw into a fore and aft direction; but no gain of thrust was thus effected, because the pressure of the water on the plane rudder acted wholly athwartships, and had no forward component.

"A figure showed the construction for finding the proper inclination of the surface of the deflecting rudder at its forward edge to a fore and aft line, and also for approximately estimating the probable gain of thrust through the forward component of the reaction of the water upon the rudder. Draw CA to represent the speed of advance of the screw through a solid ($= \text{pitch} \times \text{turns per second}$); cut off from it CB to represent the *real slip* of the screw relatively to the water of which it lays hold; so that BA shall represent the speed of the vessel relatively to the water at her stern *before* that water is acted on by the screw,

and AB the backward speed of that water relatively to the vessel. On BC as a diameter, draw a circle. Lay off the angle ACD to represent the obliquity of any given strip of the surface of the screw to a fore and aft line, and let CD cut the circle in D . Join BD ; this will represent, in direction and magnitude, the velocity which the strip of screw surface in question impresses on the particles of water. Join AD ; this will represent the resultant velocity and direction of the motion, relatively to the vessel, of the particles of water, after having been acted upon by the given strip of screw; and this also will be the proper direction for a tangent to the surface of the rudder, at that part of its forward edge which receives the water from the given strip of screw surface.

“By repeating the same process for a series of strips of the screw blade at different distances from its axis, a sufficient number of tangents might be determined to enable a mould for the rudder to be constructed.

“From the preceding construction, it appears that the proper form for the deflecting rudder was not a screw surface; and, in particular, that the obliquity to a fore and aft line at the forward edge of the rudder did not, like that of a screw surface, go on continually increasing from the boss outwards, but reached a maximum at a point opposite that strip of the screw surface whose obliquity is such that AD is a tangent to the circle BC ; beyond which point the obliquity of the rudder continually diminishes, while the distance from the axis of the screw increases.

“The screw blades that are moving from the rudder would produce forward thrust by diminished pressure on its convex surface, just as those that are moving towards it produce forward thrust by increased pressure on its concave surface.

“To obtain an approximate representation of the gain of thrust through the forward component of the reaction of the deflected stream upon the rudder: let fall DE perpendicular to AC ; make $AF = AD$; then if all the particles of water acted on by the screw were deflected into a direction right aft, the thrust would be increased in the ratio $\frac{BF}{BE}$ giving $\frac{EF}{BE}$ as the proportionate gain of thrust from the water acted on by the given strips of screw surface and deflecting rudder surface; and

the mean value of that fraction for the whole depth of the rudder and screw would be the proportionate gain of thrust on the whole. But the deflecting rudder acted only on the horizontal or thwartship component of the oblique motion of the water, and not on the vertical component; hence, about *one-half* of the before mentioned gain (that is, the mean value of $\frac{E}{2} \frac{F}{B E}$) may be taken as the proportion borne by the thrust gained through the rudder to the thrust of the screw alone, supposing the apparatus to be perfect in its action; and if we take seven-tenths of that theoretical gain as the actual gain, the proportion borne by that actual gain of thrust to the thrust of the screw alone may be estimated as $= 0.35 \frac{E}{B} \frac{F}{E}$.

“The drag produced by this rudder when the ship is under sail alone, may be estimated as bearing the same proportion to the drag produced under the same circumstances by the screw that the theoretical gain of thrust bears to the thrust of the screw alone.

“The deflecting rudder might be expected to improve the steering of the vessel; for when the ordinary plane rudder was put over, the obliquity of the current from the screw caused it to continue to press partially on the wrong side of the rudder until the angle made by the rudder with the keel became equal to the greatest angular obliquity of the current; whereas when the deflecting rudder was put over, the proper action of the current upon it commenced immediately.”

78. *The Naval Constructor on Ironclads.*—“The following is the substance of a paper read by Mr. E. J. Reed, at the Institution of Naval Architects, the object of which was to explain the manner in which the Bellerophon, Lord Warden, and Hercules targets were constructed, and the reason why their several forms were successively adopted, with a view to their being placed on the records of the Institution.

“Leaving out of consideration the smaller ironcased vessels, such as the Scorpion, Wyvern, Enterprise, Favourite, and some others, together with the 4½-inch plated wooden vessels, there had been five modified systems of construction adopted, viz., the Warrior, Bellerophon, Minotaur, Lord Warden, and Hercules.

The Lord Warden might have been omitted from the category, as the construction of ironclads with wooden hulls would probably soon be discontinued.

"The sides of the Warrior and Minotaur had some peculiar features of construction. The former was the first iron-clad ship designed in this country, and her designers had a very difficult problem to solve, and that they accomplished this with success was proved by the fact that it retained its superiority long after other targets had been built with the view of surpassing it. The target and the Warrior's sides were identical in construction, and were formed of a series of vertical iron frames ten inches deep, and about two feet apart, covered with a skin plating nine-sixteenths of an inch thick, against which were placed two thicknesses of teak, the inner ten inches thick, and the outer eight inches, the whole being faced with a $4\frac{1}{2}$ -inch armour-plate. Two important features of this target were the double skin-plating above and below the line of ports, and the external stringers upon the iron frames between the ports, which were introduced with a careful regard for the structural strength of the hull and its resisting power against shot and shell. The adoption of this form he was convinced was not the result of a lucky chance combination of parts, or a mere attempt to imitate a wooden ship's side in connection with an iron hull, but a carefully elaborated design to effect a preconceived object, and was a remarkable example of the ability brought to bear in this country on the solution of mechanical problems as soon as the necessity for their solution arose.

"The chief difference between the preceding and the Minotaur target was in the reduction of the wood backing of the latter, and an equivalent increase in the weight of the armour.

"One layer of 9-inch teak alone was used in this, which was covered with plates $5\frac{1}{2}$ -inches thick; the frames and skin-plating being the same in both targets. With the objections raised by some persons to this departure from the original model he did not agree, and when in the course of his duty he had to confer with the Controller of the Navy and his officers concerning the Bellerophon, they came to the determination to adopt the same system, namely, less wood and thicker plates, contrary to the opinions of those who saw perfection in the Warrior target. The experiments made

with these targets had proved that they were right in preferring the side of the Minotaur to that of the Warrior, and established the fact that those who preferred the latter were in error, which was proved by the discovery that in two out of three rounds fired at the Minotaur target from the $10\frac{1}{2}$ -inch gun, throwing 150 lbs. cast iron spherical shot, powder was used, the effect of which was to raise the striking velocity of the shot from 1,620 to 1,744 feet per second. The change in the powder used was made after the first shot had been fired, and invalidated all the comparisons based on the report of the trial previous to the discovery of the fact that this powder had been used. It is now known that the sides of the Minotaur, Northumberland, and Agincourt, are stronger than had been supposed, and there was no reason to suppose them inferior in strength to the Warrior. Considering the immense cost of building these large vessels, and the time required for the purpose, the knowledge that no mistake had been made in designing their armour, and that they are really as strong as their designers proposed, would be very gratifying to the country.

“In designing the Bellerophon target, it occurred to him that there were two points in which the Warrior and Minotaur targets might be improved; first, by crossing the vertical iron frames with horizontal frames of approximately equal strength, spaced like the other frames, which would add greatly to the stability and strength of the structure; and secondly, that the risk of shot or shell passing through the frames would be greatly diminished, and the resistance of the frames more effectually elicited wherever a shot or shell might strike, if the skin of the ship were considerably thickened. In other words, it appeared desirable to extend throughout the entire structure the double skin-plating and the external stringers. These features constituted the characteristic merits of the Bellerophon target; and it was a source of satisfaction to him to know that the germs of these improvements could be traced in the structures designed by his predecessors. By virtue of the combined and horizontal 10-inch frames connected by the doubled skin of $\frac{3}{4}$ -inch iron many important advantages were gained. Together they constituted an enormously strong and rigid structure, exceedingly well adapted to bear the armour under all circumstances; while the double skin and external stringers

(to which butt straps were fitted in the case of the Bellerophon herself) increased the longitudinal strength of the ship to a wonderful extent. The description of the Bellerophon target would be completed by saying that the armour was six inches thick, backed by ten inches of teak, and that one large angle iron, ten by three and a half inches, was substituted for two angle irons used in the Warrior in the formation of the external frames of the plates.

“These explanations would furnish the true reasons for riveting the external stringers to the outside of the Bellerophon skin plating, and how little the adoption of that arrangement had to do with the idea of giving direct support to the armour plates, which he mentioned, because it had been supposed, and publicly stated on various occasions, that these edge plates were adopted in imitation of quite a different system, and with the view of rigidly backing up the armour; which was an entire mistake, for much as he would like to discontinue the use of teak in the construction of iron-clads, and to make their hulls wholly of iron, he was of opinion that a rigid iron backing was attended by many disadvantages, and so far was he from valuing these edge plates as direct armour supports, that he and his colleagues caused them to be reduced in depth behind one of the plates of the target, and to a great extent in the ship also, expressly in order to keep them from too close contact with the armour, and they had done so because it appeared to him objectionable to bring the force of a blow so directly and fully upon that portion of the hull proper of the ship which is immediately in front of the shot as these plates would otherwise tend to bring it, especially if placed closer together. The object of putting armour on a ship being to protect the hull as effectually as possible, it would not be advisable to have a very rigid backing, as direct contact with the skin of the ship would transfer a great portion of the shock of the shot to that skin, whereas a slightly flexible backing allowed the force to expend itself on the armour, which was placed there expressly to receive it, and thus saved the skin, which was a very important point. He had given this matter very careful consideration, and had seen the soundness of his conclusions very strongly confirmed. There was one test easily applied, but which was usually applied in a manner the very reverse of what it should be, which

was whenever a shot struck a plate supported by close rigid edge plates upon a line of support, it was found that the plate was comparatively little injured on its surface, but if the backing was removed it was found that a trench had been cut in the back of it by the edge plate. The evident inference was that the edge plate must have been driven back on that which was behind it, and thus have risked the destruction of the inner skin. Had the external frames or stringers of the Bellerophon been situated within a few inches of each other, he would have thought that circumstance so serious as to have deterred the department with which he was connected from carrying out the plan; but with the frames two feet apart, the shot did not cause the edge plate to cut into the armour, but merely to buckle up under the force of the blow without injuring the skin; at the same time he was well aware that if the edge plates were brought closer, the force of the blow would be distributed over a greater surface, but it would still be upon the skin of the ship, instead of, as it should be, on the armour plating.

“As to the Lord Warden target, very little need be said about that. It was at first intended that this vessel should have an ordinary frigate side, covered with $4\frac{1}{2}$ -inch armour, and the only opening he saw for improving it was to solidify the frame in the wake of the armour: the advantages in favour of so doing being greater than the disadvantages resulting from it, as the shot or shell would have three times the thickness of timbers to pass through before it could let water into the ship. In the case of an ordinary wooden iron-clad frigate, when the plate and outer planking had been pierced between wind and water, there was nothing to prevent the water from entering the ship, though the frames themselves might not have been materially injured. He had therefore carried out his idea in the case of the Lord Warden and the Lord Clyde, the thickness of the solid timber side at the particular part referred to being thereby increased from nine inches to about two feet seven inches.

“After the armour had been ordered, and the ship was in course of construction, it was thought desirable to increase its powers of resistance, if practicable, behind the battery deck. By altering other weights it was found that an extra one and a half inches of plating could be carried quite round the ship for a

width of ten feet. As this gain could not be added to the armour-plates, which were already manufactured, it became a matter for consideration how to apply it to the greatest advantage. It might have been placed immediately behind, and in contact with the armour-plates; or on the frames of the ships behind the planking; or on the frames of the ship, but inside; or inside of the inner planking. Eventually he decided that the proper place for it would be between the frame and outer planking, and it was inexplicable to him how anybody could maintain that it would have been better to have placed it inside of everything, because supposing the armour-plate to be pierced, there was every probability that the inner plate would be driven entire, or in fragments, among the crew. There was one way of meeting this objection, by supporting it on iron frames, but this was impracticable in consequence of the whole weight at disposal being insufficient for both the frames and plating, and there were other objections to the use of these iron frames in addition to the thick wooden sides.

“The advantage of placing it on the outside of the frames of the ship was an important one. A ship's side had to resist shot and shell, and one of the most important things to be guarded against was the explosion of a shell within the wood backing. When the *Warrior* was designed, it appeared improbable that a shell could ever be driven through the armour-plate and explode in the backing, and on this ground, therefore, a great depth of wood backing was free from objection. But since then it had been proved that four and a half inches of plating was not proof against a shell, and he, therefore, felt it necessary to object to the thicknesses of the backings and armour, so that a shell which could be driven through the armour should not remain to explode between the outer and inner plating, as in that case several of the armour plates might be stripped from the side. This was guarded against in the *Bellerophon* target, because it was not likely that a shell which could cut its way through a 6-inch armour-plate, would be less in length than the thickness of the backing, namely, ten inches; and the importance of the precaution was amply verified, for the shell that did penetrate the plate was stopped by the iron skin behind it, and its explosive force expended outwardly. By placing the extra iron plate upon the frames of the ship in

the manner already described, the same object was accomplished in a proportionate degree in the case of the Lord Warden.

"The Hercules target was constructed on the same principle. In the vessel itself, provision had been made for 9-inch armour at the water-line, and a wood backing varying from ten to twelve inches. The same assumption was made in respect to the thickness of the side of the Hercules as in that of the Bellerophon, viz., that a shell which could penetrate through the armour would be at least twelve inches in length, and that the armour-plate, backing, and skin of the ship must all three be pierced before serious injury could be inflicted on the structure.

"Though differing a little in dimensions, the arrangement of frames, skin-plating, external girders, and armour-plates of the Hercules target resembled that of the Bellerophon, though the former had a source of strength not possessed by the latter in a second wood backing, supported by a second series of frames and skin plates. The adoption of this part of the construction was not merely on account of its supposed excellence as a shot-resisting arrangement, but as a means of making good use of the wing bulkheads. These wing bulkheads served as a second line of defence against splinters, and as an impediment to the flow of water through an injured place in the sides to the hold of the ship; also of enclosing a passage by means of which access to the ship's side could be effected in the event of repairs being required, and for other purposes. In the case of the Hercules, where provision had to be made for resisting the shot of 20-ton guns, it was thought that such bulkheads, when the ship had only to withstand guns of a moderate size, would not be required, and that against the larger guns it would be a more effectual defence if placed nearer to the side and made to support additional teak logs placed between it and the skin proper of the ship. The Hercules target, though penetrated by two 600-pounder shots propelled by one hundred pounds of powder striking on the same spot, may be regarded as invulnerable against any existing gun."—*English Mechanic*.

79. *Torpedoes*.—"This new branch of naval warfare," says the '*Mechanics*' Magazine, "is very little furnished with experimental data concerning the influence exercised by the incompressibility and mobility of the fluid on the extent of the radius within which the explosion of a submerged mine must prove

destructive to floating structures of ordinary strength, whether situated at the same level (when the pulsation will be considered horizontally) or placed above it (when the action pertains to the line of least resistance). We may easily conceive that the sudden ignition of a charge at a given depth beneath the surface of the water necessarily produces a succession of oscillating waves, spherical in form, the destructive energy of which is inversely proportionate to the square of its radius. We may even be justified in presuming, by virtue of analogy, that the radial destructive action varies directly as the weight of the powder employed, so that the total circumferential power of destruction vested in a given charge will be proportionate to the square of the said weight. Similar analogy would lead us again to infer that the formula whereby a charge is determined for the production of a given radius of rupture, in earth of ordinary quality, is susceptible of application in the case of submerged mines. The horizontal radius of rupture may likewise be considered equal to the line of least resistance multiplied by 1.75; while the vertical radius would equal the same quantity multiplied by 1.43 in the case of a charge proportioned to that line, that is, in the ratio of the 11-6ths of its cube. But we have no authority for going beyond a mere presumption in these matters, for certainly there can be no doubt that the peculiar kind of resistance offered by water modifies, to a very serious extent, the data which have led to the establishment of the formulæ now generally accepted for mining operations. For a given depth and a proportionate charge, the horizontal radius of rupture is the element mainly curtailed by the nature of the fluid; and this, in a great measure, accounts for the increase of the vertical radius, as well as for the extraordinary height to which a column of water will be raised by the explosion of a submerged mine. We thence feel little inclined to attribute any preponderating influence to the extinguishing effect of water at the instant of explosion, because it is obvious that the loss in horizontal power is not accompanied by a corresponding loss in the vertical. The slower the combustion of the gunpowder is, the more the ratio between the two elements will be disturbed in favour of the vertical. It will be the same if the initial force of the explosion be dependent for strength on the temperature of the gases. On the other hand, the more the

rate of combustion is rapid, and the force of the compound employed made independent of the temperature of the gases, the better it will be for the horizontal radius of destruction. Under water, then, we need gunpowder of the best quality, and, moreover, such arrangements in the construction of the magazine as will secure space for the more complete combustion of the grains before the contact of the gases with the water has exercised any prejudicial effect. We should for the same reasons prefer pyroxiline or gun cotton, inasmuch as its action may be made extremely energetic, irrespectively almost of the heat attained by its gases. Furthermore, it must be obvious that great advantage might flow from the plan of confining the explosion in that direction where it is chiefly needed. Two experiments occur to us as remarkably useful for illustrating the influence exercised by the incompressibility of water on the horizontal pulsation of submerged mines or torpedoes. Firstly, a box containing 100 lb. of gun cotton was placed 8 ft. below the surface of the water and 3 ft. from a double row of piles 10 in. thick, with stones between the two rows. This charge was equivalent to about 300 lb. of ordinary cannon powder, to which quantity corresponds a line of least resistance equal to about 14 ft. in ordinary soil, giving a horizontal radius of rupture equal to 24 ft. When fired, however, the gun cotton did not extend its action beyond a radius of 15 ft., while it had the power of throwing up a column of water about 200 ft. high. The row of piles was moreover destroyed. Secondly, a barrel containing 400 lb. of gun cotton was placed 10 ft. below the surface of the water; its force was equivalent to a charge of 1,200 lb. of gunpowder, to which correspond a line of least resistance measuring 22 ft. and a horizontal radius of rupture equal to 38 ft. When fired the explosion took effect on a wooden hull 18 ft. distant, and threw up a column of water to a height of 400 ft. We allude with pleasure to these examples, on account of their being the results of a more suitable compound than gunpowder for submarine explosions. It follows that, unless the object to be destroyed is brought into immediate contact with the magazine, there is hardly any chance of a torpedo proving fatal, even in the case of most powerful charges.

“When we thus analyse the action of these machines, it is easy to understand why, despite the vast scale on which they were

used both by the Russians and the Confederates, the result they gave did not correspond to the general expectation. In fact, during the whole course of the American civil war, it was proved in all cases of boiler torpedoes fired by electricity that, through the absence of contact and of the extremely limited horizontal radius of rupture, the explosion was more calculated to alarm than to do harm. The certainty of contact between the magazine and the object which had to be destroyed was one of the main features that characterized David Bushnell's first torpedo plan. In determining it, he may not have been guided by a well-founded knowledge of the reasons which rendered contact necessary; but he seems to have instinctively felt that by adhering to such a plan he was sure of eliminating every possible chance of failure, besides securing the maximum effect possible from a given charge. His cause of failure obviously, then, sprang from the difficulties of the mechanical problem, and not from the unsoundness of the theory he had allowed himself to be guided by. Mr. Woods, chief engineer of the United States Navy, took the same view as to the importance of contact when the recent events of the civil war led him to believe much good might be derived from the employment of torpedoes for offensive purposes, somewhat after Bushnell's idea, but on a much more practicable and formidable style. Confederate engineers also adopted the same principle when they modified the torpedo into an offensive implement of naval warfare. It will be well for us, therefore, not to lose sight of this condition, proved to be so valuable both in theory and in practice, should we ever decide on taking the hint given us from the other side of the Atlantic, and make torpedo boats an auxiliary means of defence and of attack for the protection of our coasts, harbours, and much-neglected colonies.

"So far as it is possible to judge from the official documents annually published by order of the Federal Navy Department, it seems but fair to give the Confederate Service credit for the idea, and the attempt, of creating the fourth class of torpedoes as an offensive rather than as a purely defensive implement, destined to grapple with the overpowering superiority of the Federal navy. The most successful specimens of this new class appear to have issued from Charleston, where the principal manufactory of torpedoes happened to be located. They consisted of small iron

boats tapered at both ends, and thus bearing a very marked resemblance to the cigar ship lately launched on the Thames. On a total length of about 64 ft. they had a circular midship section measuring from 5 ft. to 6 ft. in diameter, and were capable of steering at the rate of 6 knots an hour. They were provided with a longitudinal float midway between the keel and the top part of the hull. These floats, one on each side, contributed with the keel to strengthen the structure, and at the same time to steady its motions in rough water. The internal capacity was destined to the boilers, which occupied the fore end, the engines situated aft, the steering apparatus placed midway between the boilers and the engines, and, lastly, the magazine for a limited number of shells. The upper part of the hull, where the structure is nearly cylindrical, is left open, forming a narrow rectangular cut about 15 ft. long and 30 in. broad. This opening is protected by bulwarks about 18 in. high. Fore and aft of this cut, the hull is entirely closed and tapered to two points, the stern cone being slightly the longer of the two. The keel is carried aft under the cone to within 8 ft. of the point, so as to afford stiffness to this section and support the rudder, which the remaining portion of the stern thus completely protected. Through the cone's extremity, the shaft worked a two-bladed screw, not above 40 in. in diameter. At the bow end the funnel first attracts attention, as the only object capable of giving the alarm to an unsuspecting enemy; and next to this, the most salient object is a pole supporting a pulley, almost at the cone's summit. This pulley conveys a rope from the central aperture of the hull to near the end of a shaft 24 ft. long, which is suitably hinged on to the bow, so that by pulling the rope this shaft can easily be lifted and its fore end brought alongside the aperture. The appearance of the torpedo boat thus constructed reminds one forcibly of a sword-fish. When immersed, the central part of the hull is only 1 ft. above the surface of the water; hence the upper edge of the central bulwark is nothing more than 30 in. above the water-line. The furthestmost end of the hinged shaft carries the torpedo, which for this special service was made of copper. It measured about 25 in. in length, 10 in. in diameter, and was provided with a particular fuse, invented by Major Lee, of the Engineers. Of these torpedo boats, called 'Davids' by the Confederates, as many as

nine were found in Charleston Harbour on its occupation by the Union forces. It will not be difficult, however, to understand that, despite this large number, there could not be many favourable opportunities for employing them. By day-light the guns of the Federal men-of-war would have made short work of them; while in the obscurity they could not be sure of approaching a ship in the proper direction, as happened to be the case when a 'David' attacked the new 'Ironsides;' neither were they able to steer clear of the torpedo spars and nettings with which the Federals protected their ships at anchor against submarine damages of this sort. Nevertheless, they are highly creditable to the ingenuity of the Confederate engineers, taking into consideration the difficulties under which they were labouring, and at the same time most interesting, as embodiments of many fundamental principles, which may still be turned to good account in future improvements.

"The first attempt at laying down torpedoes in Charleston Harbour was made at the commencement of the year 1863, followed in course of a few months by the appearance of the torpedo boats or 'Davids,' and by the simultaneous adoption on both sides of torpedo shells attached to the bows of some iron-clad rams and monitors. To these circumstances we believe it reasonable to trace the invention of an improved class of 'Davids' on the part of Mr. Woods, of the United States Navy. His first proposals are, at least, set forth in a letter, dated November 23, 1863, calling the attention of the Navy Department to an apparatus fit for destroying vessels of any class, and removing submerged obstructions—the means requisite for performing this duty to consist of a suitable armour-clad screw vessel provided with mechanism for placing torpedoes beneath hulls at the rate of one every ten minutes, and employing them with certainty of effect and with no risk to the operator. Alluding to the causes of failure of similar destructive appliances, Mr. Woods attributes them either to untimely explosion, or to want of contact between the magazine and the hull to be destroyed. To produce within two months a working vessel in accordance with these conditions, Mr. Woods did not ask for any larger sum than £10,000. In a subsequent communication with Admiral Gregory, Chief of the Bureau of Construction, the inventor explains further details.

He sets the total length of his vessel down at 80 ft., takes from the Monitor type a turret for look out, and a low iron-clad hull for operating safely under fire; suggests the propriety of a broad beam and twin screws, and promises a still quicker succession of discharges. The vessel is to be essentially offensive in its power of destruction and rate of speed. Fortunately for Mr. Woods the department he had to deal with differs in many respects from the institution which, despite popular clamour, still sits at Whitehall, and rules over the destinies of our navy. He, in fact, made rapid progress, since the report referring to the experiments conducted with his apparatus and shells is dated May 31, 1864; and, before the close of the year, the 'Spuyten Duyvil,' iron-clad torpedo boat, was ready for service. It was usefully employed in removing obstructions in the James River, after General Lee's surrender, April, 1865. The main principle to which Mr. Woods' torpedo shells owe their success consists in placing the magazine beneath the bottom of a vessel, then causing it to rise in a vertical position, on being liberated from the apparatus; and, lastly, ensuring its explosion during contact in such a direction that the whole power of the shell will be spent upwards, or, in other words, against the object it touches. Hitherto, torpedoes have been permitted to act spherically when exploding, whence springs the loss of power we have alluded to at the beginning of this article. In Mr. Woods' shell, on the contrary, the centre of gravity is so placed that the charge cannot help taking a vertical position; moreover, an air space is secured in the upper portion of the chamber by means of a thin diaphragm, whereby a direction is given to the explosion and its force fully developed. If, now, care be taken that the weight of the water displaced by the shell shall be greater than that of the shell itself the charge will be buoyed up, and continue to rise in a vertical position until it has reached the vessel beneath which it is supposed to have been placed. The particular way in which Mr. Woods realizes these conditions is as follows:—The exterior shape of the shell is that of a cylindro-conical projectile, provided with a raised stud at the base, three lungs near the lower end, and a sliding shutter at the upper end of the cylindrical portion. Internally, we find that the conical head is filled with metal, whereas the cylindrical body is formed of thin iron. Moreover, in this cavity, a lateral

tubular chamber is formed, of which the diameter is a little less than the internal radius. At the bottom of this chamber is a nipple communicating by a suitable channel with the enclosing cavity. This nipple is intended to receive the sliding shutter, giving free access to it. At the opposite end to that of the nipple, a spherical ball is made to rest on a pin driven diametrically through the chamber, and furnished with a cord, so as to permit of its being forcibly withdrawn when the cap is to be struck. The powder is allowed to fill the residual cavity to a level with the pin, where a diaphragm confines it, and at the same time leaves an air space at the upper part of the shell. Under these circumstances the magazine tends to rise with the cone downwards, until the base touches the bottom of the hull. On the pin being then withdrawn, the spherical weight falls, strikes the cap, and ignites the charge, which takes an upward direction, in consequence of the air space thus provided above it.

“With regard to the next important condition of Mr. Woods’ principle, viz., that of placing the torpedo beneath a hull, and thence disengaging it prior to explosion, it is attained by mechanical means, which would require a far more elaborate description than our space will permit. The main points, however, are simple enough to be intelligible without any need of drawings. At the fore-end of the vessel the special machinery is located which has to convey the shell from the inside to the outside, through apertures suitably prepared. At the bows, and in the direction of the keel, this machinery acts on a long iron lever, called the operating bar, made of wrought-iron, with the corners removed. Within this bar is an iron rod, the rear of which projects beyond the rear of its envelope. This operating bar, with its rod, is guided through a sphere into an airtight chamber, where it receives a species of hollow cylindrical head, long and large enough to contain the shell, which is inserted with its base inwards, so that the rod, to which are hinged two small levers, forming together a system of jaws, grasps the stud at the base and thus holds the magazine. The sluice-valve, which cuts off the interior of this operating chamber from the water outside, is now raised, and the bar driven out in a convenient direction until it has reached the limit of its forward motion. Then the inner rod comes into play, forces the lever apart, releases the stud,

and ultimately ejects the torpedo, when nothing further has to be done than to withdraw the pin, and thereby cause the charge to be ignited. After the explosion, if another shell has to be fired, the sluice-valve is dropped down, a slide valve below the operating chamber is opened, to let the water contained in the box run into the hold, where the pumps eject it; and then the new torpedo is introduced, its stud is seized by the jaws of the inner rod, the upper and lower slide-valves are closed, the sluice-door opened, and thus the operation above described repeated over again. Such are, in a few words, the main features of this last phase of torpedo warfare. We trust this description may prove useful in enlightening our own engineers, and calling public attention to a question which may of itself alone decide the fate of our naval supremacy in most parts of the globe. Bermuda, Halifax, and Quebec are no longer really in our keeping so long as they may be visited with impunity by a squadron of turreted monitors, preceded by a couple of torpedo ironclads. No man in England can imagine that our penetrable ships and light guns can ever be a match for Dahlgren ordnance of 15 in. to 20 in. calibre, protected by impenetrable armour, and torpedo shells dropped out of iron-cased steamers."

SECTION THIRD.—DOCKS,

80. *The Hydraulic Lift Graving Dock*.—A very elaborate paper on this subject was read by the inventor, Mr. Edwin Clark, C.E., before the Institution of Civil Engineers. Of this we give the most important parts, leaving out the historical introduction, &c., which the reader will, however, find in the August number of the "Civil Engineer and Architect's Journal." *The Thames Graving Docks*.—"It was with a view of meeting, as far as possible, the objections to existing systems, that the author proposed the hydraulic lift graving dock as the most efficient and economical substitute for the requirements of the Victoria Docks.

"It was ultimately constructed by a totally independent company under 'The Thames Graving Dock Company.' The necessary capital, originally £105,000, was raised in shares of £1,000 each, and was privately subscribed.

"The site selected was a plot of 26 acres of level land, lying

between the Victoria Docks and the Thames, and below the level of high water. This site admitted of a direct entrance from the docks, with a permanent water level, without the cost and delay of a special entrance from the river. The soil is a deep bed of bog and alluvial mud, on a substratum of gravel. The only excavation necessary was the lift pit, and its deep entrance to the dock, where a cofferdam was employed.

"The depth of water in the lift is 27 feet ; over the remaining water space it is only 6 feet, which is the maximum draught of the pontoons. In this shallow water space there are eight pontoon berths, separated by jetties for workshops and access ; each berth being 60 feet wide, and from 300 feet to 400 feet long and surrounded by brick retaining-walls. The bottom was covered with a level layer of peat clay, to prevent leakage to the gravel beneath. A sluice through the surrounding bank renders it easy, at low water, to empty the whole of the space ; but when this is done, a dam must necessarily be thrown across the upper end of the dock, to cut off the access to the Victoria Docks. The area of shallow water is 16 acres, affording sufficient space for floating fifteen or twenty pontoons, which, it was estimated, was about the number that might be kept employed by a single lift.

"The docking of a vessel consists of two distinct operations. First, the direct raising of the weight on the lift ; second, the transportation of the vessel to any convenient position for its repair on the pontoon.

"The lift is a direct mechanical appliance for raising the vessel by means of hydraulic presses. It consists of two rows of cast-iron columns, each 5 feet in diameter at the base, and 4 feet in diameter above the ground-level, and sunk about 12 feet in the ground. The clear space between the two rows is 60 feet, and the columns are 20 feet apart from centre to centre, and are placed on each side of the excavated lift pit, in about 27 feet of water. There are sixteen columns in each row, giving a length of 310 feet to the dock ; but as vessels may overhang at each end, there is a practical working length of 350 feet. The columns were sunk in the usual manner, three or four being thus fixed per week. When the requisite depth was attained, the base was filled with concrete, and covered with a layer of 2 inch planks, to act as a cushion for the cast-iron seat on which the press rests.

No great accuracy of position is required, as the suspended load tends to bring all the columns vertical, and if any column should, during use, be even sensibly thrust deeper into the soil, the ram follows its work, independent of the level of the press. The columns support no weight ; but act solely as guides for the cross heads of the presses, which move in slots reaching from the top of the presses (just clear of high water) to the top of the columns. The column is covered by a cap, and each row is firmly connected together at the top by a wrought-iron framed platform, running from end to end of the dock on each side. This platform forms a convenient permanent scaffold for raising the rams. The whole length of a column is 68 feet 6 inches. A scale is printed on each column to register the motion of the cross heads while rising or falling.

“The presses and girders are managed as follows :—Each column encloses a hydraulic press of 10 inches diameter, with a length of stroke of 25 feet ; the top of the press is just clear of the highest water, and it is kept in place by a collar or diaphragm in the column. The rams are solid, and each carries a boiler plate cross head 7 feet 6 inches long, thus extending 1 foot 9 inches beyond the column on each side. From the ends of the cross head are suspended, by wrought-iron bars, two iron girders each 65 feet long, which extend entirely across the dock to the corresponding column and press on the opposite side. There are thus sixteen pairs of suspended girders, lying at the bottom in 27 feet of water, when the presses are lowered, but rising above the surface, when the presses are raised. They form a large wrought-iron platform, or gridiron, which can be raised or lowered at pleasure, with a vessel upon it. The detail of the machinery is identical with that employed at the Conway Tubular Bridge ; and those who saw that bridge raised have only to imagine thirty-two tubes side by side instead of two, and they will have a perfect representation of the lift. The main girders are 5 feet 9 inches deep, of wrought-iron trussed with a cast-iron top flange. The sectional area of each ram being 100 circular inches, a pressure of 2 tons per circular inch gives 200 tons as the lifting power of each press, or 6,400 tons for the whole lift ; but to find the available lifting power, there must be deducted 620 tons, which is the weight of the rams, cross

heads, chains, and girders, leaving 5,780 tons for the pontoon and vessel. The presses were tested at $2\frac{1}{2}$ tons per circular inch. The girders are designed for carrying the vessel as a load at the centre, although the load is distributed by the pontoon, and the wide base used for the blocks. The water is forced into the presses immediately beneath the collars at the top, this being an accessible position.

“The grouping of the presses was an important consideration. If each press were worked entirely independent of its neighbours, it is evident that precisely the same quantity of water must be thrown into each press to avoid unequal strain. Again, if the whole number were supplied from a common head, the slightest excess of weight at any part of the platform or gridiron would lower that part, the water passing back through the pipes to the presses where less pressure existed; the same difficulty would be experienced with two groups, however arranged. Stability is, however, secured by arranging the presses in three groups. One half of the whole number, occupying the upper half of the lift form one group, consisting of sixteen presses. The remaining eight presses on one side form a second group, and the opposite eight form the third group.

“The presses in each group are all connected, so that perfect uniformity of pressure is secured in each as regards the individual presses; while the three groups are so arranged that their centres of action form a tripod support, upon which the pontoon is seated. As any one point of the tripod may be raised or lowered without regard to the other two, by the most simple manipulation, the pontoon can be either maintained perfectly level or any inclination can be given to it that may be desired.

“Any pair of presses may be instantly cut off in the valve-room by means of a plug during the operation of lifting, without interrupting the process. One or more of the end pairs is almost invariably out of use, except with vessels of the largest class. No delay, therefore, arises from the failure of a collar or pipe, and even should a press burst—which appears an impossible contingency—the water can only escape slowly through the half-inch pipe which feeds it; and by opening the escape valves in the other groups, vessels, partially raised, descend slowly and steadily into the water.

“Additional provision against such a contingency has been provided, by an arrangement which gives instantaneous means, in the valve-house, of isolating every press from the rest. For this purpose, a special series of valves is provided for each group, which can be closed simultaneously by means of an eccentric shaft. This arrangement, which forms so prominent an object in the valve-house, has been found unnecessary, and will not be again employed. The force-pumps are $1\frac{7}{8}$ inch in diameter. There are twelve pumps, worked by direct action by a 50 H.P. engine; six of these pumps are used for the large group, and three pumps for each of the smaller groups. The power when required is increased by cutting off one or more of the pumps. The engine-house is, unfortunately, 112 yards from the lift, the water having to be driven all this distance through pipes only $\frac{1}{2}$ inch in diameter. On account of the distance of the engine, a valve-house, for the manipulation of the presses, is erected on the platform alongside the dock. During an operation the engine continues to pump, and the valveman throws the water into either group, or to waste, at pleasure. The raising of a vessel occupies about twenty-five minutes. The pipes and presses are, to a considerable extent, sheltered from frost by their position: and during the severest cold, a few occasional strokes of the engine are found sufficient to keep all in motion, and prevent congelation.

“The pontoons are not essential for raising, or docking a single vessel, for it is evident that the lift, as described, is all that is required for that purpose. The girders might be connected together by other longitudinal girders, so as to form a sufficiently rigid platform, or the whole might be formed into a pontoon, which would support a vessel after it was raised. Such an arrangement would be more economical and convenient than any ordinary dock, but it would accommodate only a single vessel; whereas, by the use of separate pontoons, an indefinite number of vessels may be placed afloat, whilst the most costly part of the system remains constantly available.

“The following is the arrangement adopted:—An open pontoon, proportioned to the size of the vessel to be docked, is selected. Keel-blocks and sliding bilge-blocks, adapted to her shape, form part of the pontoon, which is placed on the girders, and sunk with them to the bottom of the dock. The vessel is brought

between the columns, and moored securely over the centre of the pontoon. By lifting the girders, the keel-blocks are first brought to bear under the keel of the vessel; the side-blocks are then hauled in, by chains laid for the purpose on each side the dock, and the gridiron and the pontoon, with the vessel upon it, are then all raised by the presses clear of the water. The pontoon is provided with valves in the bottom, and thus empties itself of water. The valves are closed, and the girders again lowered to the bottom, but the pontoon with the vessel upon it, remains afloat. Thus, in about thirty minutes, a vessel drawing 18 feet of water, is left afloat on a shallow pontoon drawing 4 feet or 6 feet, and may be taken into the shallow dock prepared for its reception. These docks are surrounded by workshops and tools, with shelter for the men close up to the bulwarks of the ship. The vessel is, in fact, brought bodily into the centre of a convenient workshop. It is taken to the smiths', or the carpenters', or the machine shops, according to the nature of the repairs required, and is moved easily from one to the other.

“The number of vessels that can be thus docked is limited only by the number of pontoons, each pontoon constituting a separate and independent dock. The pontoons, which are all about 58 feet wide, vary in length and depth according to the class of vessel intended to be docked, and are rectangular in form, and open decked. The sides are vertical, and are strengthened longitudinally and transversely by wrought-iron girders, running from side to side and from end to end, and thus forming a series of rectangular divisions. The pontoons are divided into water-tight compartments, by means of bulkheads formed of the girders, each compartment being provided with a circular valve in the bottom, closed by a screw-shaft. The transverse girders are 8 feet apart, and support the bilge-blocks on their upper flanges. In the largest pontoons these girders form inclined planes, declining in height towards the centre, to facilitate the running-in of the block-frames. There is a strong longitudinal centre girder, with a broad top flange, for supporting the keel-blocks; on each side, the two other longitudinal girders are placed equally distant, and in the line of the side-blocks. There are seven pontoons at present in use, their dimensions being given in the following table:—

No.	Length.	Depth.		Net Tonnage.	Cost.
Feet.	Feet.	Feet.	Inches.	Tons.	£
1	241	6	2	1,750	5,130
2	241	5	6	1,650	6,086
3	201	5	6	1,450	5,725
4	201	5	6	1,450	5,683
5	157	5	0	1,100	4,100
6	134	5	0	930	3,600
7	321	7	0	3,000	10,853
8	281	Partly constructed.		2,450	...

The cost of the lift and other machinery was:—

	£
The lift complete and fixed, including columns, presses, girders, and pipes	20,300
The 50 H.P. condensing engine and pumps, boilers and connections, including the valve arrangement (not a necessary part of the apparatus)	3,600
The connecting pipes, including all testing, fitting, and fixing, supply of workshop tools, experiments, &c.	1,628

“It may be remarked that a high-pressure engine would be more convenient, and far more economical.

“There are, doubtless, many details which may be materially improved after seven years' experience; but it is a proof of the simple character of the machinery, that no modification, or renewal, or repair of any kind has been necessary, although at the end of last year 1,055 vessels had been lifted, of an aggregate tonnage of 712,380 tons, without a single casualty.

“No remark is necessary on the calculations employed in so simple a machine. The area of each pump being $3\frac{1}{2}$ circular inches, their aggregate area is 42 circular inches. Similarly, the aggregate area of the thirty-two presses is 3,200 circular inches. The action, disregarding friction, is therefore identical with that of a lever, whose arms are respectively 42 and 3,200. The respective velocities and pressures are thus obtained by direct proportion, the power being a 50 H.P. engine on the long end of the lever, and the weight lifted being the vessel on the short end; while it may be remarked that, in a stone dock, the power employed bears no proportion to the work done, and is always immensely greater.” Here follows a statement of the advantages

of the system under various circumstances. For this we have not space, but conclude by giving the following brief summary of these advantages :—

- “1st. Its economy, as well in its first construction as in its subsequent maintenance.
- 2d. Its adaptability to almost any situation, especially in harbours or tideless seas.
- 3d. The capability of almost indefinite extension, by the construction of additional pontoons, or as regards the lift, by the addition of extra columns.
- 4th. The simple and durable character of all its parts, and their perfect accessibility.
- 5th. The short time required for its construction and erection.
- 6th. The rapidity of its manipulation, and the small staff required.
- 7th. The convenient access afforded to all parts of the ship, and, especially in painting iron ships, their free exposure to light and air.
- 8th. The freedom from strain with which vessels, even in cargo, may be docked.
- 9th. The means afforded of rendering any area of shallow water available as a dock for the largest vessels.

“The above characteristics are the result of direct experience ; but it may be useful to indicate others that may be anticipated.

“In the first place, it is evident, that this system affords ready means, by the construction of a shallow canal, of transporting the largest vessels in cargo either across an isthmus, or over river shallows ; and of removing vessels of war inland, either for their protection, or for their employment as a means of internal defence.

“The pontoon affords a convenient and economical method of avoiding the risk and cost that attends the launching of new vessels. It is intended by the Company to build vessels on their pontoons, which may be grounded for this purpose on a level bottom, and an immovable platform will be thus at once secured. The launching will then be reduced to simply lowering on the lift. In this manner vessels of any dimensions may be constructed in a shallow estuary.

"Vessels may, when unemployed, be laid up and kept dry under shelter, and thus preserved from decay, while the launching of a whole fleet would only be the work of a few hours.

"No naval establishment possesses sufficient dock accommodation to provide for the numerous casualties that occur during war. It will not be doubted, that a lift, with sufficient pontoons, would prove of the utmost value, in affording immediate means, after an action, of docking a whole fleet of gun-boats and other craft, thus leaving the existing stone docks for routine use.

"Lastly, it is evident, that should this system become as universal in its application as the author confidently believes it must eventually do, such a result would inevitably lead to important modifications in the general arrangements of all large naval establishments. If fleets can thus be laid up, and vessels be built and navigated in any shallow-water space, no necessity can exist for that large area of floating dock accommodation which is now required; and a considerable portion of the enormous expenditure which characterizes such works may be economized."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION NINTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

Modern Legislation in regard to the Construction and Equipment of Steam Ships,—Engineer, Feb. 23d.

Fitments of Steamships,—Engineering, March 23d, Illustrated.

The Hydraulic Propeller,—Mech. Mag., April 13th.

On attempts to Prevent Compass Deviation,—Engineer, June 29th, p. 409, Illus.

The Illumination of Buoys,—Mech. Mag., June 22d.

Monitors,—Engineer, June 8th.

Ironclad Gunboats,—Mech. Mag., May 25th.

The Loss of the London,—Prac. Mech. Jour. for April, Illus.

On the Connection of Plates of Iron and Steel in Shipbuilding, especially such as are subject to sudden tensile strains, by N. Barnaby, Assistant Constructor to H. M. S. Navy,—Civil Engineer and Architects' Jour., June.

On the Dimensions of Ocean Waves,—Scientific Review, April 1st.

Balanced Rudder,—Engineering, March 2d.

On the Strength of Rivetted Joints in Shipbuilding,—Engineering, March 30.

Portable Life-Preserving Raft,—Prac. Mech. Jour., Nov., Illus.

Ship Launching, H. M. S. the Northumberland,—Mech. Mag., April 13th.

The Plough Coulter Bow,—Engineer, May 11th, p. 333, Illus.

Fouling and Corrosion in Iron Ships,—Mech. Mag., Sept. 7th.

The Compasses of Iron Ships,—Engineer, Feb. 16th.

On a Method of Propelling Ships in a Calm by the action of the Waves,—
Prac. Mech. Jour., April.

Ship Launching, the Northumberland,—Prac. Mech. Jour., June.

Notes on Steam Vessels,—Engineering, August 31st.

Clyde Dredging and Dredger,—Practical Mech. Jour., Jan., Illus.

Hydro-Propulsion,—Engineer, Nov. 16th.

Broadside and Turret Ships,—Engineer, Jan. 5th.

New Mode of Propelling Boats,—Mech. Mag., Oct. 26th, Illus.

Worthing Pier, by R. Rawlinson, C.E.,—Engineering, Oct. 12th, p. 288, Illus.

Turrets or no Turrets,—Prac. Mech. Jour., Aug., Sept., Oct., Illus.

Twin-Screw Engines of the Mary Augusta,—Engineer, Oct. 26th, Illus.

Life Boat Oars,—Mech. Mag., July 6th.

Valves for Docks,—English Mech., Feb. 23d, p. 309, Illus.

The Madras Pier,—Engineering, March 24th, Illus.

Sheathing Iron Ships,—Mech. Mag., Jan. 5th, p. 5, Illus.

Registered Tonnage of Steamers,—Engineer, April 6th.

Ruthven Steering Apparatus,—Mech. Mag., Nov. 2d, p. 276, Illus.

Iron Floating Dock at Sourabaya, Dutch East Indies,—Engineer, Aug. 24th, p. 127, Illus.

Unarmoured Ships,—Engineer, May 4th, p. 325.

Compound Marine Engines for the Danube Steam Navigation Company,—
Engineering, Oct. 12th, p. 280, Illus.

Floating Dock for Bermuda,—Engineering, Oct. 19th, p. 294, Illus.

Resistance of Armour,—Engineering, July 6th, p. 16.

Light-draught Steamers for the River Godavery,—Engineering, Nov. 2d, p. 338, Illus.

The French Fleet,—Mech. Mag., June 8th.

Chain Cable Testing,—Engineering, May 25th, p. 339.

The Turret Ships,—Engineering, Feb. 2d, p. 73.

Marine Engineering,—Engineering, Feb. 23d, p. 113.

Chaplin's Boat Lowering Apparatus,—Engineering, Feb. 23d, p. 125, Illus.

The Manœuvring of Ships,—Engineering, March, 16th, p. 164.

The Depolarisation of the Northumberland,—Engineer, Sept. 7th, p. 176, Illus.

Ironclad Frigate Bellerophon,—Engineering, Jan. 5th, p. 4, Illus.

Experiments on the Difference between the Resistance of Water to Floating and Immersed Bodies,—Engineer, pp. 152—174, Sept. 7th.

What shall We do with our Old Fleet,—Engineer, Nov. 16th. In this article the conversion of our wooden vessels into iron-plated ones is treated of and illustrated.

Rocket Apparatus for Saving Life,—Engineer, Nov. 16th, Illus.

Graving Docks,—Engineering, Aug. 10th.

Torpedoes,—Mech. Mag., April 20th.

Woolwich Guns and American Monitors,—Mech. Mag., Nov. 9th.

The (American Monitor) Miantonomoh,—Mech. Mag., June 22d.

Canal Boat Engines,—Engineering, July 6th, Illus.

Steam Jet Propulsion,—Engineering, Oct. 26.

United States Torpedo Vessel "Spuyton Duyvil",—Engineering, Oct. 26th.

Ruthven Hydraulic Propeller,—Engineer, April 13th.

Cleaning the Bottom of Cruising Ironclads,—Engineer, June 22d.

Construction of Harbours,—Building News, Feb. 9th.

- Mechanical Appliances in Shipbuilding*,—Mech. Mag., Feb. 23d.
The Tide Shriek,—Engineering, June 1st, Illus.
On the Slip of Screw Propellers,—Mech. Mag., Jan. 12th, and Feb. 9th.
Naval Reconstruction,—Mech. Mag., Feb. 9th.
Floating Dock at St. Thomas,—Engineering, April 23d, Illus.
The Pallas,—Engineer, April 27th.
Halstead's Proposed Turret Ships,—Engineering, Jan. 12th, Illus.
Engine Room Hatches,—Engineer, Jan. 19th.
Penn's Patent for Wood Bearings,—Engineering, May 4th, Illus.
The Introduction of the Screw Propeller into the United States,—Engineer, May 11th.
A Machine for Cleaning Ships' Bottoms,—Mech. Mag., July 13th.
Modern Legislation in Regard to the Construction and Equipment of Steam Vessels,—Journal of the Society of Arts, Feb. 23d.
American Monitor at Sheerness,—English Mechanic, July 13th.
Hydraulic Steering Apparatus,—Mech. Mag., Oct. 5th, Illus.
Notes on Steamers,—Engineering, Sep. 28th.
Steam Dredging Machine, Grand Canal, Amsterdam,—Engineering, Sep. 14th, Illus.
Ruthven's Propeller, the Nautilus and the Waterwitch,—Engineering, April 13th and Nov. 2d.
The Construction of Iron Vessels, by James Lyall,—Civil Engineer and Architects' Journal, March 1st, p. 75.
Our Ironclads,—Mech. Mag., April 13th, p. 225.
On the American System of Turret Ships,—Engineering, April 6th, p. 225.

DIVISION TENTH.

TELEGRAPHS.

81. *The Atlantic Telegraph*.—In the August number of the "Practical Mechanics' Journal," the Editor has given a full and most graphic account of the various points connected with this grand undertaking. We can only find room for a portion of this paper; referring the reader to the number of the journal in which it appears as above named.—(a) "*Paying-out and Picking-up of Machinery*."—This, generally speaking, is much the same as that employed for paying out the 1865 cable; a few alterations, which are considered *improvements* (however, this much remains to be seen), have been introduced. The character of the picking-up gear will be understood from the following brief extract from a contemporary :—'Amongst other things it has been connected with a pair of trunk engines, made by Messrs. John Penn and

Son, which work up to 80 horse power, and which are employed for hauling in the cable over the stern of the vessel, if such a course should become necessary. The picking-up gear fitted to the fore part of the vessel is quite new, and is very much more powerful than that used last year. The trunk engines which drive it are exactly similar to those connected with the paying-out machinery, and the apparatus itself consists of a pair of drums, each about 6 ft. in diameter, fixed upon parallel shafts at a short distance apart. The drums are each furnished with a powerful brake, and are driven through an arrangement of gearing interposed between them and the engine, this gearing being arranged so that it can be worked at two different speeds. The cable will be led to the hauling-in drums over a series of V-guide pulleys interposed between them and the V-wheels carried by a frame fixed on wrought-iron girders projecting over the bows of the vessel."

(b) *The Laying of the Cable.*—"On July 6th the shore end of the Atlantic cable was successfully landed at 3 P. M. The tests were perfect. The *William Cory* proceeded to sea, and paid out slowly. The weather was fine. The cable of 1865 was tested at noon to-day, and found as perfect as when laid.

"On the 8th, the *Noriel*, *Blackbird*, *Pedlar*, *Skylark*, and *William Cory* returned to Berehaven at 3.30 A. M., and proceeded to sea to splice the main cable to the shore end on Wednesday morning.

"On Friday, the 14th, about 4 P.M., the splice with the shore end was completed, and the great ship then fairly started the operation of laying an electric cable across the Atlantic for a second time, the signals being perfect throughout the entire length of the cable.

"The paying out has continued without interruption, and comparative fine weather has attended the expedition. On July 20th, all the cable in the after tank having been expended, the shift was made without difficulty.

"On Friday, the 26th July (the day on which these pages are passing through the press), it is expected that the line will be completed. Everything thus far has gone well. We trust, too, that soon after this part of the *Practical Mechanic's Journal* is in our readers' hands, the cable may be in operation.

“Having now laid before our readers the latest information, it may be as well, ere concluding, to add a few remarks upon some parts of the cable we before especially referred to, as well as to place on record some of the facts bearing hereon.

(c) *The Shore Ends*.—“As before indicated, the Irish end was stowed on board the *William Cory*. Its tensile strength has, we believe, not been ascertained; but it must be something very high indeed, when we remember that the outer covering is formed of wires, or rather iron bars, almost as thick as ordinary poker, and it weighs upwards of 20 tons to the mile—nearly double the size and strength of the largest submarine cable ever made. This end is about 30 miles in length.

(e) *The Actual Cable*.—“We have before briefly referred to the general construction; but to render this paper as perfect as possible, it has appeared desirable to append the following wood-cut illustrations and description. (The cuts referred to are not given here, but the reader will find the ‘actual cable’ illustrated in a succeeding paragraph, p. 358.)

“The cable consists of a copper strand of seven wires, as seen in cross-section fig. 2, six laid round one, from which mode of arranging them no kinking or bending is likely to break all the wires in the same place and so destroy the continuity. The copper strand weighs 300 lbs. per nautical mile, and is imbedded in Chatterton’s compound, which cements the conductor firmly to the gutta-percha covering and prevents it from lying loosely in the interior. Each of the copper wires is of No. 18 gauge, or $\cdot 048$; gauge of strand, No. 10, or $\cdot 144$. The conducting wires are insulated by four layers of gutta-percha, laid on alternately with four thin layers of Chatterton’s compound. The weight of the entire insulation is 400 lbs. per nautical mile, the diameter of the core $\cdot 464$, and its circumference $1\cdot 392$. In the foregoing particulars the cable now on board the *Great Eastern* resembles that of last year. The external protecting covering, however, is much less expensive than that of 1865, because the thick strands surrounding the iron sheathing wires have not been saturated with india-rubber and tarry preservative compounds, the plain manilla yarn alone being used. As such tarry matters have not yet proved sufficient to protect the sheathing wires of cables, the omission is probably of little importance. The ex-

ternal covering this year consists of ten solid wires of homogeneous iron, slightly galvanized. Each wire is then surrounded separately with five strands of white manilla yarn, as shown in the cuts, and the whole laid spirally round the core, as more particularly seen at fig. 1, which is padded with common hemp, saturated with a preservative mixture, not of a tarry or non-conducting material, likely to interfere with testings for faults. The cable's weight in air is 31 cwt. per nautical mile, in water 14 cwt. 3 qrs., and the breaking strain 8 tons 2 cwt. The galvanizing of the sheathing wires is said to have lowered their breaking strain, yet to have increased that of the cable, because the elongation of the wire now allows a portion of the strain to be borne by the Manilla yarn before final breakage takes place. The sheathing wires, it will be noticed, surround the core like a long spiral spring.

(e) *The Tests.*—"This year, as we have before said, great improvements have been made in the plan and apparatus for testing the electrical condition of the line. The Telegraph Construction and Maintenance Company have secured the professional services of Professor William Thomson and Mr. Cromwell Varley, who are the consulting electricians of that company.

"Last year the tests for determining the condition of faults and also the strength of earth currents were performed on board ship. This year accurate tests are made at both ends of the cable, and a continuous exchange of results is telegraphed from one to the other, the information which the shore gives to the ship being of the highest importance to enable those on board ship to find out the position of a fault accurately and rapidly should any occur. The principal batteries used for testing are on board ship, and the shore has to read off and decipher these indications.

"It is of the utmost consequence that the most competent electricians should be at each end of the cable, and it was, therefore, finally decided that one of the consulting electricians shall be at each end of the line during the operation of paying out. Professor Thomson is gone in the *Great Eastern* with Mr. Willoughby Smith, while Mr. C. F. Varley remains at Valentia.

"It is not our intention here to divine as to who are the real inventors of the several improvements which have been made for the purpose of testing either occasionally or constantly; suffice it

to say, that the alterations and additions which have been made appear for the most part to have originated at different times by Professor William Thomson and Mr. Varley, the consulting electricians; and we believe that considerable merit is due to Mr. W. Smith, electrician to the contractors, for his method of maintaining the continuous tests during the operation of laying.

“In order to maintain communication and continue the tests whilst the Atlantic is being traversed, the following method is being adopted.

“A battery, with one of its poles connected with the earth, has its other pole connected with the galvanometer, which it deflects a few degrees as the current runs through the cable. This current is constant, and should it suddenly increase or decrease the deflection, it would at once show that something is wrong with the line. On reaching Valentia it is made to encounter a large amount of resistance, a resistance greater, as a rule, than that of the whole of the Atlantic cable. The feeble current afterwards escaping from the resisting medium passes through an exquisitely sensitive galvanometer, and thence to the earth. Thus the galvanometer index of both is deflected by the current, and the observers at both ends of the line can see what is going on. Supposing the battery power to be such that 10° deflection is registered on each galvanometer, increased power suddenly applied may be made to give 15° , and more power still 20° . When, therefore, it is intended to send signals, a deflection of 15° thus produced is equal to a dot, and 20° to a dash, of the Morse alphabet. The needle, however, never comes back to zero, because of the original and constant current giving still 10° deflection, consequently, all the time messages are passing the line is still subject to electrical tests. Should the index suddenly come back to zero and there remain, it would be a proof that the conducting wire of the cable was broken inside its insulating sheathing of guttapercha. Should a violent and great deflection take place, it would show that the cable was so injured that the current escaped from it into the sea. At the shore end then, Mr. Varley, who watches the signals, is able to see what Messrs. Thomson and Smith are doing on board ship. No battery power will be employed at the shore, but if it should be desired to signal

to the ship, a momentary wave will be abstracted from the current passing through the line, by the aid of a large or small condenser, the size of the condenser influencing the magnitude of the deflection, so that the land operator can thus produce a long or short signal, equivalent to the dot and dash of the Morse alphabet.

(f) *Transmitting Apparatus.*—"In the event of the cable being successfully laid, the apparatus for sending messages is so arranged as to leave the cable in a neutral condition immediately after the transmission of each signal, so that the line will be instantly ready for conducting another. We shall shortly describe the mode by which this is effected.

"The receiving instrument will be Professor Thomson's reflecting galvanometer, with which many of our readers are now familiar. Where long proper names have to be read by the movements of the ray of light, and the deflections are rather uncertain, repetition of the word is now necessary, whereas the expense might be avoided did the galvanometer print its own messages. This might be done by the aid of a horizontal cylinder with a chronometric movement, covered with photographic paper of a sensitiveness proportionate to the intensity of the moving ray of light. Professor Thomson is aware of the advantages of this expedient, and has included it in his patent.

(g) *The New Signal Code.*—"Among the many improvements which are to be tried in working the wire when laid, is Captain Bolton's new system of codified signals, by means of which a single numeral often represents a whole sentence, and always a word. This code has for its basis a numerical arrangement, by which all words and letters of the English language can be expressed by groups of figures. All words and letters of any other language capable of being rendered in the English character, can also be likewise expressed. The object of this arrangement is to facilitate the speed of transmission of messages, and to prevent the liability to error in the rendering of a message. The telegraphic symbols used to express this code are the dot and the dash. By this system the necessity of mixing dots with dashes is obviated, errors arising from the use of a combination of both are avoided, and the signals are equally simple and effective, whether used with a short and long signal, or right or left de-

flections; the latter being the most expeditious. The code is divided into five parts, and they are as follows:—

“Part I. provides 110 signals, and expresses the letters of the alphabet.

Part II. provides for 1,000 signals, limited to three figures, and forms the ‘spelling code,’ by which any word in any language having English characters can be spelt by syllables.

Part III. provides for 10,000 signals, limited to four figures, and forms a special code applicable to commercial and political intelligence, and frequently recurring names of places, months of the year, days of the month and week, time, hours, &c.

Part IV. provides for 100,000 signals, limited to five figures, and expresses every word in the English language alphabetically arranged, and such sentences as are coded, and is called the ‘vocabulary and sentence code.’

Part V. provides for 127,000 signals, limited to six figures, and expresses the name of every known place in the world.

“Each part is readily distinguishable by the number of figures in the group; for instance, a group of three figures must refer to Part II., and a group of five figures to Part IV., and so on.

“In the formation of this method of codification, a system of page and line has been established, indicating, by a single glance at the group of figures, the particular page and line in the code-book to which they refer, thus considerably facilitating the rendering of messages from code into ordinary language.

“The advantages alleged to be obtained by this system of codifying by figures are the following:—Gain of speed, extreme simplicity of code, simplicity of instrumentation, and non-liability to mutilation in passing through different countries; facility of repetition, and its applicability to any language by translation without causing loss of time.

“It is reported to have been established, although we are not prepared to believe it when in so early a stage, that from the result of the recent experiments through the cable when on board the *Great Eastern*, this system is capable of effecting, at the very least, a gain of 100 per cent. over that now in use, thus making one cable do the work of two. Thus, no matter what instruments are used, the advantages to be obtained by the use of the code will follow. For example, an instrument sending by the ordinary

telegraphic symbols letter by letter, at a rate of eight words per minute, can transmit by the use of this code at least 16, and so on.

“Objections may be advanced as to the use of a code causing probable inaccuracy; but this is not so, for a skilled operator can transmit symbols representing figures as easily as he can symbols representing letters; and the chance of error in the reading of a message by the clerk at the receiving end is extremely narrow. Errors, if they do occur, must be localized in one or more particular groups of figures, rendering them quite unintelligible and impossible even to guess at their signification; but as every group of a message is numbered, the one in which the error may have been committed is requested to be repeated, and thus accuracy is secured, and the highly objectionable practice of reading by context, which now obtains to so great an extent with telegraphic operators, often causing the mutilation of the message, is rendered impossible.”

82. *The Three Atlantic Cables.*—From an article on this subject in the ‘*Mechanics’ Magazine*’ we take the following:—“Now that the third Atlantic cable is in working order, and the second one, we hope, being grappled for, it may be interesting to give particulars of the three cables. We also show a section and exterior view of each cable, drawn to the full size, so that comparisons may be readily made.

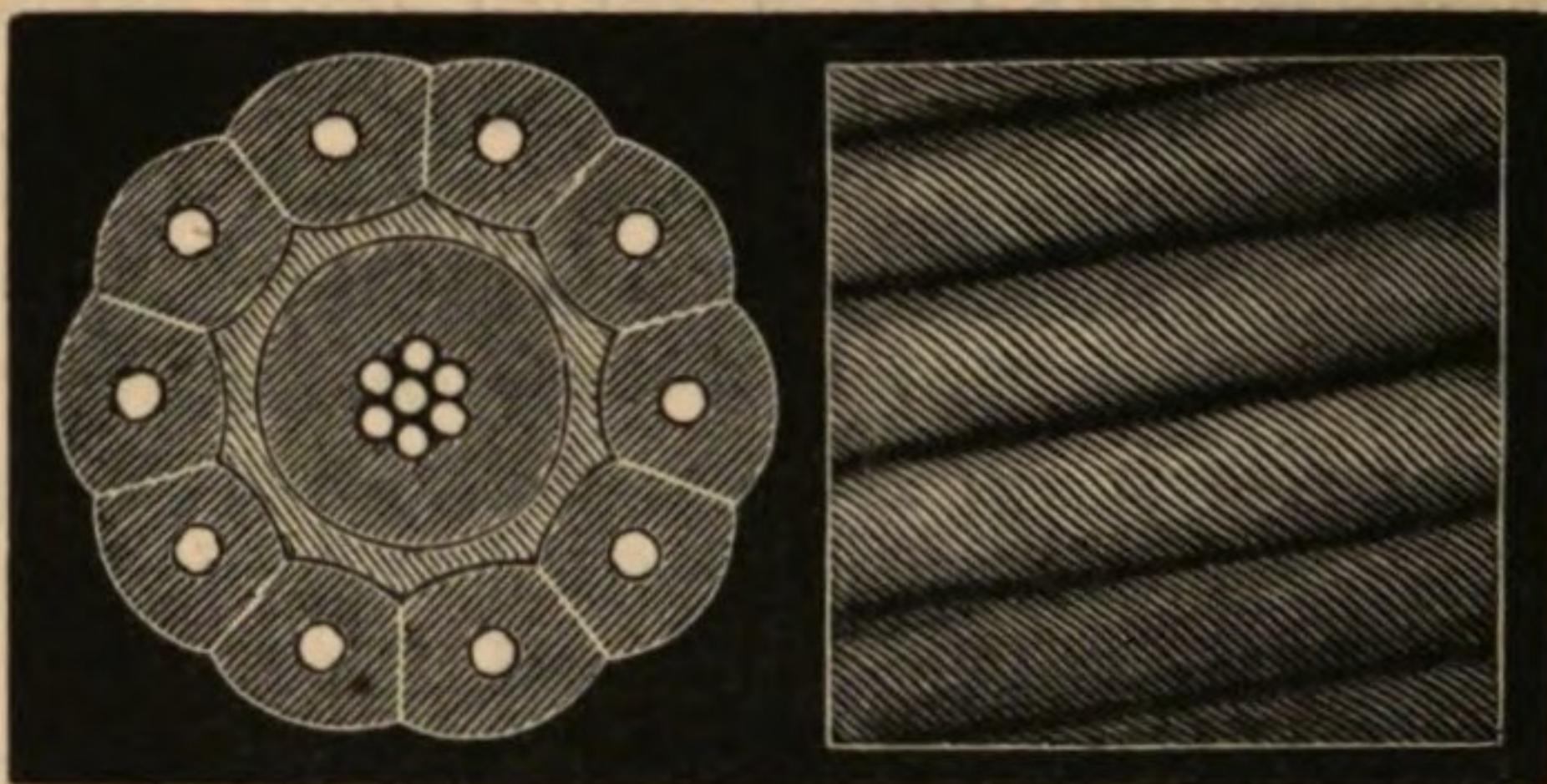
Fig. 26.



“The cable of 1858 (fig. 26) had for a conductor a copper strand of 7 wires, 6 laid around 1; weight 107 lb. per nautical mile. The insulator was of gutta-percha, laid on in three coverings; weight 261 lb. per nautical mile. The outer coat was composed of 18 strands of charcoal iron wire, each strand made of 7 wires, twisted 6 around 1, laid equally around the core, which had previously been padded with a serving of tarred hemp. Breaking strain, 3 tons 5 cwt. Capable of bearing its own

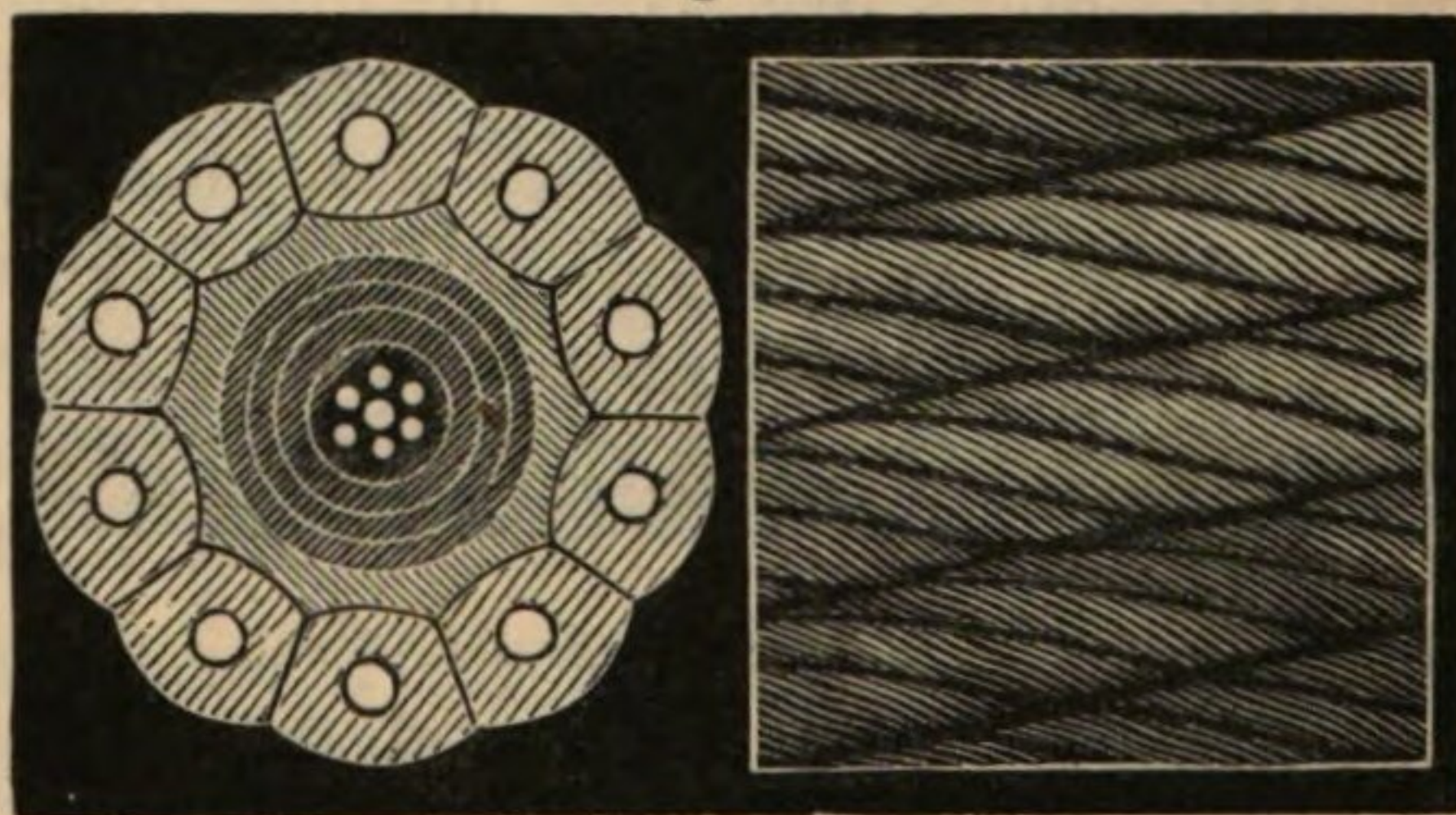
weight in a trifle less than 5 miles' depth of water. Length of cable, 2,174 nautical miles.

Fig. 27.



"In the cable of 1865 (fig. 27) the conductor was a copper strand of 7 wires, 6 laid around 1; weight 300 lb. per nautical mile. Embedded in Chatterton's compound. Insulation was effected with gutta-percha and Chatterton's compound. Weight, 400 lb. per nautical mile. The outer coat was 10 solid wires, drawn from Webster and Horsfall's homogeneous iron, each wire surrounded with tarred Manilla rope, and the whole laid spirally around the core, which had previously been padded with a serving of tarred jute yarn. Breaking strain, 7 tons 15 cwt. Capable of bearing its own weight in 11 miles' depth of water. Length of cable, 2,300 nautical miles.

Fig. 28.



"The present cable (1866, fig. 28) has for a conductor a copper strand of 7 wires, 6 laid around 1; weight, 300 lb. per nautical mile. Embedded for solidity in Chatterton's compound. The insulator is 4 layers of gutta-percha laid on alternately with thinner layers of Chatterton's compound; weight, 400 lb. per nautical

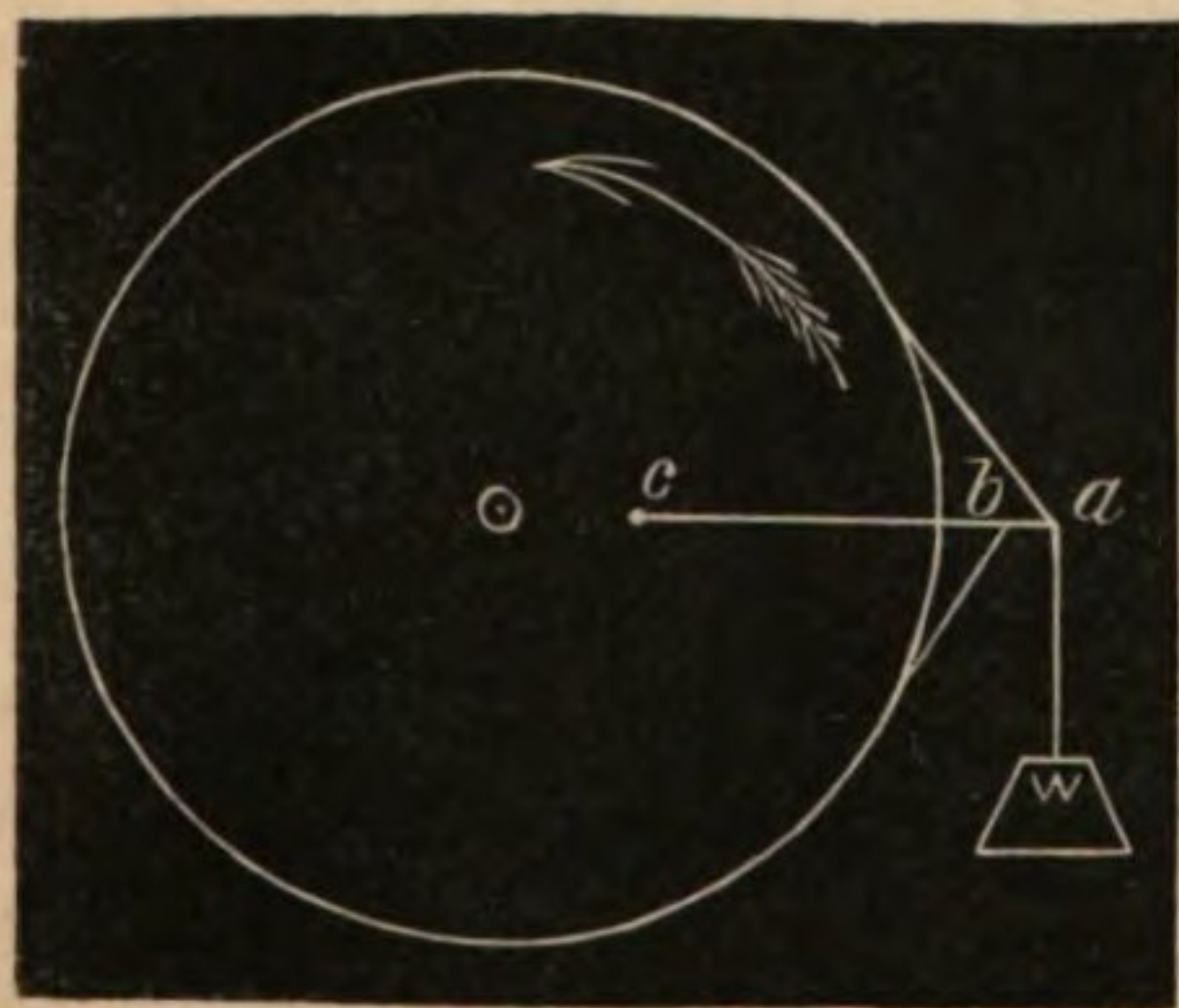
mile. The outer coat is 10 solid wires drawn from Webster and Horsfall's homogeneous iron, and galvanized, each wire surrounded separately with 5 strands of white Manilla yarn, and the whole laid spirally around the core, which had previously been padded with a serving of tarred hemp. The breaking strain is 8 tons 2 cwt., and it is capable of bearing its own weight in 12 miles' depth of water. This length of cable is 2,730 nautical miles, part of which is to be used for completing the cable that parted last year."

83. *On the Two Atlantic Telegraph Cables.* By Fleeming Jenkin, Esq., C.E., F.R.S., in the *Scientific Review*.—"Last year, in the October and November numbers of the *Scientific Review*, I had the honour to write two articles about the '*Times*' Letters on the Atlantic Telegraph Expedition.' This year we have two cables, but no letters to write about; and it is satisfactory, on looking over my old articles, to find that I may refer the reader to them without having any corrections to make. The following is a description of the 1865 cable:—The conductor is a seven-wire strand of copper, weighing 300 lbs. per knot. The diameter of each wire is 0.048 inch; the diameter of the strand 0.144. This strand is insulated by four layers of gutta-percha and Chatterton's compound, weighing 400 lbs. per knot, and measuring 0.464 inch in diameter. This core is served with, or wrapped in, tarred hemp, weighing about 2.2 cwt. per knot; and round this serving lie ten iron or steel wires, each of them separately covered with five strands of tarred Manilla hemp. The wires were made of Webster and Horsfall's homogeneous iron, sometimes called iron, sometimes steel, and were 'bright,' not galvanized; the diameter of each is 0.095 inch, and the weight of all the wires is about 13.75 cwt. per knot. The weight of the hempen strands round all the iron wires was about 12.8 cwt., their lay about 3 inches. The diameter of the completed cable is 1.125 inch; its weight in air about $35\frac{3}{4}$ cwt., and in water 14 cwt.; its breaking strain 154 cwt., equal to 11,000 fathoms, or 11 knots of itself, hanging vertically in water. With this breaking weight, it stretched from $2\frac{1}{2}$ to $4\frac{1}{2}$ per cent. The mean resistance of the copper conductor per knot, at 24° centigrade, was 4.272, Ohm's or B.A. units; the mean resistance of the insulator per knot, at the same temperature, was 349 millions of those units.

"The 1866 cable differs very little in construction from that of the previous year. No change was made in the copper or gutta-percha; the wires were made of a somewhat different quality of iron or steel, and were in part, I believe, supplied from France. They were galvanized instead of being bright, and were wrapped in white hemp instead of tarred yarns; the tar being no longer needed as a protection against rust. The cable was, I believe, a little lighter and a little stronger than that of 1865. But I have not at present such minute information concerning it as I have already given of its elder (or younger?) brother. The most important change consisted in galvanizing the wires, to prevent the rust which had actually been observed in some places on the 1865 cable under the tarred yarn. For all purposes of laying, speaking or testing, the two cables are practically identical. For repairs, the wires of the 1866 and the hemp of the 1865 cable will probably last longest. We have had convincing proof that the wires, even of the 1865 cable, do not seriously alter in strength during one year.

"The cables this year were paid out with similar machinery to that employed in 1865. The cable was held by a drum, round which it passed several times, just as, on a smaller scale, a rope is held by being passed round a bollard or the simplest form of capstan. The drum is prevented from turning too fast by a friction strap; this strap is weighted so as to produce exactly the retarding force required, and is, moreover, arranged, as in the

Fig. 29.



annexed diagram, so that no change in the rubbing surfaces will affect the retarding strain. The retarding force, exerted by the break-strap, is obviously equal to the difference of tension on the ends *a* and *b* of the break-strap (fig. 29). There is a comparatively great strain on the end *a*, and a much smaller strain at *b*. The difference is the pull of the drum on the strap, or *vice versa*, of the strap on

the drum. Let these ends, *a* and *b*, be attached to a lever, *c a*, working on a centre at *c*, and the weight, *W*, be hung at *a*; call

the strain on the end a of the break-strap P , and that on the other end p ; suppose, moreover, the two points a and b very near the circumference of the drum, so that their pull is sensibly at right-angles to the lever ca , instead of being at a sensible angle, as in the diagram. Then we have, taking moments round c —

$$W \times ac = P \times ac - p \times cb, \text{ or } W = P - p \frac{cb}{ac},$$

and when cb is nearly equal to ac , as in the case in practice, the weight, W , is sensibly equal to $P - p$, or to the friction caused by the break-strap. This, it will be seen, is true, whatever be the co-efficient of friction between the rubbing surfaces, or however much this may alter. If the friction increases a little, the weight, W , rises a little, and this loosens the break-strap by placing the lever, ca , at a slight angle upwards, from c to a . If the co-efficient of friction diminishes, the weight, W , falls a little, tightening the break-strap. This arrangement, invented by the late Mr. Appold, may be used as an accurate dynamometer, to measure power transmitted by a shaft, and effectually prevents a greater strain than is desired coming on the cable through the agency of the break-drum, which does not, therefore, require any extraordinary attention. Certain jockey pulleys, each with its little break-strap, are placed between the ship's hold and the break, and also retard the cable a little; their chief use is to hold the slack end of the cable taut on the drum, just as a man or two may be required to hold the slack end of a rope passed round a capstan. The rope, on leaving the break-drum, passes under a pulley on a weighted lever and up again to the large stern sheave from which it shoots out, forming a very small angle with the horizon, and just touches the water about 200 feet astern. The weighted pulley riding on the flat bend of the cable is commonly called the dynamometer, because it weighs or measures the strain on the cable: as the strain increases the weight rises, and the bend in the cable becomes flatter and flatter. This dynamometer is therefore an extra safeguard, showing that the break and other retarding machinery are working properly. Inventors should turn their attention to other matters than to devising fresh modes of paying out cables. The arrangement just described works admirably, and has paid out the 4000 miles of Atlantic cable without a hitch.

“One dangerous incident certainly did occur. Several turns of the cable came up entangled one with another out of the hold in such condition that they could not be passed over the drum. The paying out had to be stopped instantly, and a very considerable time had to be spent in disentangling the rope, while great and dangerous strains could only be kept from arising by a skilful management of the ship.

“The retarding strain on the cable was about 12 cwt. The cable would bear nearly 8 tons ; and these figures show the merit of the form adopted. The 2400 fathoms of the cable, if hanging vertically from the ship in water, would have weighed 35 cwt. The weight of the cable, as it actually stretched from the ship to the bottom in almost a straight line, upwards of 16 miles long, was upwards of 11 tons. The strain on the cable, if it had been hanging in a catenary curve, emerging from the water at the angle observed (about $9^{\circ} 30'$), would have been upwards of 100 tons ; but the actual strain was only 12 cwt. And this observed strain entirely agrees with that to be deduced from the mathematical theory which was first published by Prof. W. Thomson in the *Engineer* (October 1857), and is fully treated of by Messrs. Brook and Longridge in a paper read before the Institution of Civil Engineers in 1858. The chief conclusions of this theory may be stated as follows :—To lay any cable, however light, quite taut we require nearly the tension due to a weight of the cable hanging plumb from the surface to the bottom : but, by increasing the bulk of any cable, if we do not at the same time increase its weight in water, we may, by laying a little slack or waste cable, diminish the tension very greatly. The explanation of this is that the increased bulk increases the resistance which the water offers to being displaced by the cable as it falls, and also increases the friction by which the water tends to prevent the cable from slipping through it end-ways. By this frictional resistance and resistance to displacement, the water itself bears up a great part of the weight of the cable, and it bears up more the faster the ship goes and the faster the cable is paid out.

“The testing arrangements this year were, in every respect, different from those of 1866. To describe them in any detail would require a separate article, but the result of the system may be given in a few words. A constant insulation test was main-

tained on board ship. A second insulation test was maintained on shore. The ship could signal to the shore, or the shore to the ship, without destroying or altering the insulation test on ship-board. And, finally, if a fault did occur, its position could be almost instantly ascertained by the double ship and shore-readings; unless, indeed, the fault were so bad that all communication with shore was broken, in which case no difficulty would be experienced in fixing the position of the fault by the single ship's test. By this system a fault could not possibly occur without being instantly observed, for at no time was the insulation test abandoned; and yet the frequency of telegraphic communication with the shore, by which ship's news could be sent and shore news received, instead of being diminished, was increased to the utmost. It would be difficult to praise too highly this novel and beautiful system carried out by Mr. Willoughby Smith, under Prof. Thomson and Mr. Varley, and arranged by him conjointly with them.

"Whether the injuries caused last year were accidental or the result of malice will now probably never be known. No similar injuries occurred this year, and the fault which led to the loss of the cable in 1865 has not been recovered, so that we remain ignorant of its nature.

"The total length of the 1866 cable is about 1858 nautical miles, and the distance run was 1669 miles; that of the 1865 cable, 1896 nautical miles, and the distance run about 1670 miles. The insulation resistance per knot of the 1866 cable, when laid, was, by Mr. Latimer Clark's tests, 2,200 millions of B.A. units. That of the 1866 cable has not been published, but is still higher. The great increase in this resistance over the figures given above is partly due to the low temperature of the bottom of the ocean, and partly to the great pressure which is invariably found to improve the insulation.

"The recovery of the 1865 cable in good condition is obviously much more important as an engineering achievement than the submersion of many new cables. It is also more important to the shareholders, for it removes from their property the imputation of being liable to any excessive risk of total loss or rapid depreciation. The public has never distinguished between shallow and deep-sea cables as an investment: the former have long

been a safe property, but the many deep-sea failures threw discredit on all submarine cables. Now this discredit is, or should be, wholly removed, for cables are actually safer in deep seas than in shallow ones; and it was only because of the belief that one fault or flaw in a deep-sea cable must be fatal to it that engineers on all occasions chose a shallow rather than a deep-sea route. Even now I should personally prefer shallow water, because, even if the outer covering decays, the valuable core of the cable can be recovered from small depths; but in the Atlantic, if the steel or iron rusts, and any accident occurs, the cable can no longer be repaired. It may be urged, with much show of reason, that no accident can occur in great depths after the cable has been down long enough to lose its outer sheath; but I am not bold enough myself to set bounds to possibilities. Meanwhile it is very encouraging to hear that the 1865 cable, when recovered, showed both hemp and iron to be apparently as strong and sound as ever; while the electrical tests proved that the core had in no way deteriorated. It is one of the great advantages of the present accurate system of testing that enables the electrician to pronounce with certainty upon a point of this kind.

“The process by which the cable was recovered was of the simplest kind. The grapnel, a sort of four-pronged small anchor, was simply dragged along the bottom of the sea by a very strong steel rope. The strain on the steel rope was watched by aid of a dynamometer, similar to that already described, and when any considerable increase of strain was observed, the cable was supposed to be caught: the picking-up gear was started, and slowly hauled up the steel rope by the aid of a drum, exactly like that used for picking up, but placed near the bows of the ship. If the strain continued to increase steadily, even after the grapnel was known to be off the ground, then the cable was certainly hanging to it. The strain caused by the weight of the steel rope, by its resistance to the water, and by the flukes of the grapnel as they dragged along the sand, ranged from $6\frac{1}{2}$ to 9 tons; when more than this strain was observed, the cable was always hooked. It was just possible to haul the cable by main force to the surface without breaking it. To explain this, I cannot do better than quote a short extract from a lecture which I gave at the Society of Arts, and published in their Number for the 16th Feb., 1866—

“If a cable were laid absolutely taut along the bottom of the sea, when hooked by the grapnel it would rise a little way in virtue of its elasticity; if it stretched one per cent., by the time ten miles of it were off the ground the apex would be half a mile from the ground—a result few are prepared to expect; but the strain on the cable where caught would be very great, being equal to the weight of about twenty-four miles of the cable, though the weight on the grapnel rope would be only that of ten miles of cable. The result, therefore, of trying to raise a cable such as the Atlantic, laid taut, would certainly be to break it; but cables are not laid taut in deep water, and the Atlantic is laid with a mean slack of about twelve per cent., and in the last days we may even count on fourteen or fifteen per cent. slack; that is to say, for every 100 miles passed over, 114 or 115 miles of cable were laid. Lay on the floor 114 inches of chain, between two points 100 inches apart; lift it in the middle on a hook: the two ends will hang down in catenary curves, and when the cable at the extremities is just off the floor, the hook will be 23·3 inches from the floor. Quite similarly a cable laid with fourteen per cent. slack will, when caught by the grapnel, hang in two half catenary curves; and by the time 11·4 miles of the cable are off the ground, the grapnel will be 2,330 fathoms from the bottom—*i. e.*, at the surface of the Atlantic.

“The strain on the grapnel rope will be the weight of the cable lifted, or about 11·4 miles; the strain on the cable itself at the point of suspension will be much less, being only about $3\frac{1}{2}$ times the weight of the cable hanging vertically, or say eight miles of cable. Observe that the strain on the cable and the weight of the cable are not synonymous.

“When the two ends hang plumb, the strain on the cable at the top is half the weight of the cable carried.

“When there is little slack, the strain is much greater than the weight carried.

“If the depth were only 2,000 fathoms, the strain on the cable when brought to the surface would only be equal to the weight of about seven miles of cable. Moreover, the actual cable is not held at any point, except by its own weight, and there will be a pull at the bottom tending to haul in slack towards the grapnel amounting to several tons: but, even without counting upon slack

obtained in this way, it is clear that if the cable will bear eleven miles of its own weight, it could, under favourable circumstances, be hauled to the surface by a single grapnel.

“On one occasion the cable actually was thus lifted by sheer pulling; but at the very moment of apparent success it parted, showing that, as I anticipated, the practical chances of success by sheer pulling in the deepest water would not be very great. The engineers in charge of the expedition were perfectly well aware of this, and their object was first to try to hook the cable so near the end that it would draw along the bottom, and, hanging down nearly vertically on either side of the grapnel, come up with comparatively little strain.

“This they did not accomplish; and, after breaking the cable several times, and actually getting one of the short pieces broken off on board, they shifted their grappling ground to a point nearly 100 miles from the end, in rather shallower water—viz., 1,900 fathoms. Here the engineers practised the simple and safe plan of hooking the cable with two ships—the *Great Eastern* to the west, next Ireland, the *Medway* to the east, with orders when she hooked the cable to heave up as rapidly as possible, and to break the cable, so as to take off the strain from the *Great Eastern's* grapnel. It does not appear, from the only narrative yet published, whether the *Medway* actually did break the cable, or whether her pulling had only the effect of dragging sufficient slack from the eastward to allow the *Great Eastern* to get up the cable without too great a strain. Either result was possible; but, at any rate, the cable this time was safely made fast to the *Great Eastern*, and the 100 miles lying towards America were cut away, and so, as I understand, were lost for ever: so that the nature of the last 1865 injury will probably now never be known. The incidents described in the long diary of the dredging are wonderfully like those met with in shallow water; and the time occupied was no greater than is frequently required to repair cable in thirty fathoms. The completion of the 1865 cable was looked upon by every one as a matter of course as soon as the old end was on board; although, six weeks previously, laying 600 or 700 miles of cable in the greatest depth of the Atlantic would have been watched by all with anxiety, if not fear.

“Some uses of the double cable will be peculiarly interesting

to science. The laws of transmission of electricity can by their aid be studied as can be done by no other means. So long as one remains good, the position of any fault can be determined with extraordinary precision. By using one as a return wire, probably messages may be transmitted even during violent magnetic storms, which would stop work with one wire only. If this result does not follow, we shall at any rate obtain new and valuable information as to the probable course of earth currents and magnetic storms. When the law of transmission has been verified, the cable may be used for astronomical observations of great importance. The resistance both of copper and gutta-percha ought to tell us whether any variation occurs in the temperature of the bottom of the sea, and even whereabouts any such alteration occurs. I hope the Directors will show a liberal spirit, and allow such experiments as these to be made by competent men, and so, to put the matter fancifully, show their gratitude to science. I have not ventured to praise the men in charge of the expedition. They require no acknowledgment from any one: their work stands patent to all. But I should be glad sometimes, in connexion with Atlantic cables, to see some mention of Sir Charles Bright, Mr. Whitehouse, and others, who acted as pioneers, and at least cleared the way for the final and successful attack."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION TENTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

- Electro-Telegraphy and Electrical Science*,—*Engineer*, Jan. 12th.
Transmitting Apparatus of the Atlantic Cable,—*Engineer*, June 13th, Illus.
Laying Telegraph Cables,—*Engineering*, Feb. 23d, p. 118.
Recovering Apparatus for the Atlantic Telegraph,—*Engineer*, June 22d, p. 447, Illus.
Jones' Tablet Telegraph,—*Scientific Review*, Oct., p. 115, Illus.
Atlantic Telegraph,—*Engineer*, July 27th, p. 61, Illus.
Repairing Submarine Cables,—*Engineering*, May 11th, Illus.
Atlantic Telegraph,—*Engineering*, Nov. 2d, Illus.
Submarine Telegraphy,—*Scientific Review*, March 1st.
The Rise and Progress of Telegraphy,—*Engineer*, Feb. 16th.
The Picking up of the Atlantic Telegraph,—*Mech. Mag.*, Sep. 7th, p. 141.
Simpson's Typo-Telegraph,—*Engineering*, July 20th.
Automatic Telegraphy by A. Bain,—*Journal of Society of Arts*, Jan. 19th, Illus.

Deep Sea Telegraphy,—Scientific Review, Aug. 1st.

Signalling Speed of the Atlantic Cable.—Engineer, Aug. 3d.

Testing Submarine Cables,—Mech. Mag., April 6th.

DIVISION ELEVENTH.

AGRICULTURAL MACHINERY.

84. One of the leading shows of the year is that of the *Smithfield Club*; of the machines and implements exhibited at that held in December of 1865, we give the following description from the "Practical Mechanics' Journal."—"One of the features in the implement department which struck us this year, is the large number of portable farm and contractors' engines on view. Taking them in their order from the left of the western entrance, we find a well-arranged and constructed 10 horse-power portable engine by Barrows and Carmichael, of Banbury. It is a single cylinder engine, with a single slide bar only, and the barrel of the boiler carried flush throughout from front to back, which gives a neat and solid appearance to the engine. Fox & Walker exhibit a 6 horse-power engine; and Robey & Co. (Limited), of Lincoln (by the way, we perceive several of the old firms have been transformed into joint stock companies on the principle of limited liability), are represented by an excellent and workmanlike 12 horse-power engine. This firm have recently obtained prizes for their engines and thrashing machines in Perth, Cologne, Doncaster, Oldham, and Dublin. Allchin & Son exhibit a neat 8 horse-power portable engine with steel-plate boiler; also, a well-made, fixed, horizontal cylinder engine. We next come across the Dublin prize steam fire-engine of Shand & Mason, capable of working up to 25 horse-power with 125 lbs. pressure in the boiler. The boiler is of the vertical multitubular class, and enables steam to be got up from cold water in eight minutes. Messrs. Ruston, Proctor, & Co., of Lincoln, exhibit a couple of well-made portable engines, of 12 and 8 horse-power, respectively; and R. Hornsby & Sons are represented by an 8 horse-power engine. An exceedingly well-finished agricultural locomotive, or

traction engine, of 8 horse-power is exhibited by Charles Burrell, of Thetford; the principle of this engine is similar to the ordinary 'portable engine,' with the addition of larger and stronger driving wheels, and an over-tyre of wrought iron to prevent the liability of breakage in passing over rough roads. The motive power, as in the engines of the Aveling & Porter type, is given by an endless pitch-chain passing over a pinion on the crank shaft, and a chain-wheel firmly secured to the large driving wheel, but which may be easily disconnected by withdrawing a bolt from the nave of either wheel for the convenience of turning corners. A link motion-reversing gear is also provided, as well as a steering wheel and wrought-iron tank holding a six miles' supply of water. This form of engine has been in constant use amongst a large number of agriculturists for a considerable time, for drawing and working steam thrashing machines and straw elevators. Tuxford & Sons still maintain their reputation for portable engines by three admirably executed engines of 10, 3, and 1 horse-power, respectively. John Fowler & Co., Leeds, exhibit one of their 10 horse-power steam ploughing engines, with ploughs and apparatus complete. A useful single cylinder 8 horse-power traction engine is exhibited by Messrs. Clayton & Shuttleworth, who also exhibited a 10 horse-power horizontal cylinder fixed engine, and a 10 horse-power double cylinder portable engine. In the single cylinder traction engine a self-acting compensating motion is provided, whereby the speed of the driving wheels may be varied in turning on the road. Messrs. James & Frederick Howard, of the Britannia Iron Works, Bedford, exhibit one of their new patent ploughing and traction engines of 14 horse-power, with transverse boiler and two drums, to work either on the 'round about' or on the direct system. This engine is about to be sent to New Zealand, and we are informed that orders for several others have been obtained from the viceroy of Egypt, and some of the large landed proprietors there. A splendid field for steam cultivation is now opening out in the cotton plantations of the southern states of America, where labour is lamentably scarce at the present time, and we trust our manufacturers will not be slow in extending their energies in that direction. Aveling & Porter, of Rochester, exhibit one of their powerful traction engines which have now gained a deservedly

world-wide reputation, judging from the number of home and foreign prize medals awarded to them. The Reading Iron Works Company (Limited), late Barrett, Exall, & Andrews, are represented by a Lenoir gas engine of 1 horse-power, which they aptly term the 'Popular household motive power,' and exhibit also two portable steam engines. Edward E. Allen exhibits his patent double expansion steam engine, adapted to a portable or contractor's engine. Marshall, Sons, & Co. exhibit a well-made single cylinder 8 horse-power portable engine; and William Foster, of the Wellington Foundry, Lincoln, exhibits a 10 horse-power double cylinder portable engine, fitted with all the recent improvements, and specially adapted for farming and general contractors' work.

"Amongst the miscellaneous implements we noticed a decided novelty at the stand of Garrett & Sons, consisting of a patent straw bruiser for preparing cattle food; this machine consists of a large cast-iron drum, having a number of deep annular grooves therein, and a series of slight, but rather sharp-edged ribs, or projections, cast at intervals across the bottom and sides of the grooves. Within these grooves enter radial fixed blades, a small space being left between the edges of the blades and the ribs under the grooves, to allow the drum to revolve freely. Above this drum there is a feeding hopper, and on one side of the mouth of this hopper, and close to the drum, is fitted a feeding roller, which draws in the straw as fast as it is supplied, and effects its complete disintegration by dragging, tearing, or grinding it to shreds, between the revolving drum and the fixed blades; the resulting produce is a mass of fine, woolly shreds of straw, free from all sharp and hard particles, and much more digestible than the ordinary chopped straw hitherto used. This machine is capable of keeping pace with an 8 horse-power thrashing machine, bruising and tearing up the straw as fast as it can be fed from the thrasher. In the treatment of bean and other hard straw this machine will be found most serviceable, and we advisedly recommend it as one of the most useful additions to the implement stock of the agriculturist. In hot climates where draught oxen are extensively used, the chopped straw which now constitutes a somewhat large proportion of their diet, but which is found to be by no means suitable for them, will be most advantageously replaced by 'bruised straw.'

"A large Swathe delivery reaper is exhibited by Hornsby & Sons, Tucker & Sons, and Clayton & Shuttleworth, are both well represented by their admirably arranged and constructed combined thrashing machines, with Underhill's corn elevator, and all the most recent improvements. Messrs. Howard exhibit their renowned champion plough, B B, to which has been awarded the majority of the 'All England' prizes this autumn; also their improved haymaker, which carried off the first prize at Plymouth. We noticed a novelty here in their double furrow plough, provided with a ribbed steel beam, which imparts extraordinary lightness and strength to the implement. A new rotatory harrow, pulverizer, and twitch extirpator is exhibited by Holmes & Sons, of Norwich. This machine, which obtained the silver medal at Plymouth, forks out the twitch or stubble without breaking it; and by the fork barrel revolving at a great speed, leaves it lightly on the surface of the soil. It pulverizes the soil, moreover, to the depth of five inches in light soil, getting completely under the twitch, and bringing it up to the surface without breaking it. For clearing stubbles and for spring cultivation this implement will be most valuable. The Beverley Iron and Waggon Company (Limited) make an excellent show of carts and farm waggons, and exhibit one of their well-known reapers. A large assortment of grinding and bruising mills is exhibited by Woods and Cocksedge, and by E. R. & F. Turner—which latter firm has gained an excellent name for this class of implements.

"In the galleries, we find on our left Weston's differential pulley blocks in full action, at the stand of S. & E. Ransome & Co., and deservedly attracting a large share of attention. A more unassuming, and, at the same time, useful instrument has probably never been introduced to the public. Several ingenious three-motion churns, and a colour mixer on the same principle, are exhibited by Messrs. Carrington & Turner. The dash of the churn receives a vertical, rotatory, and oscillating motion by means of a crank, on which there is a bevel wheel, and attached to the centre of which is another bevel wheel, connected with a socket, in which the rod of the dash is placed. On imparting a rotatory motion to the crank, the dash rises and falls, and oscillates with it, whilst at the same time it receives a rotatory motion on its axis. In the colour mixer, the dash or agitator does not oscillate, but

simply revolves, and rises and falls in the mixing vessel. W. N. Nicholson, of the Trent Iron works, Newark, has a good show of haymakers and horse rakes. Brick and tile making machinery is ably represented by E. Page & Co., Bedford; Henry Clayton & Co., and John Whitehead of Preston, Lancashire.

"We noticed an excellent new patent grass-mowing machine, exhibited by Samuelson & Co., of Banbury. This machine is most simple in its construction: the small number of the parts, and the fact of the framing being entirely of iron, gives not only a light appearance, but lessens the liability to derangement. The operations of throwing the machine in and out of gear, lifting the cutter bar, &c., in lieu of being effected by hand, are entirely under the control of the driver's foot, whose attention is consequently never taken away from his horses. The bar is jointed for the facility of cutting over sideling lands, and a spring arrangement is provided for easing it over inequalities of surface. Richmond & Chandler have a large display of chaff cutters of all sizes. An ingenious compound lever cheese-press is exhibited by Hurst and Pickering; in whose neighbourhood is Hancock's useful little butter purifier, noticed by us in our last report, and which still attracts a large share of attention. Messrs. Nalder & Nalder exhibit their admirably constructed corn screens and noiseless winnower, which have attained a wide-spread reputation. At this part of the gallery we unexpectedly came across a well-arranged horizontal tank engine, by Henry Kinsey, of the Robin Hood Works, Carrington Bridge, Nottingham. These engines are entirely self-contained, requiring no expensive foundation, but simply a good floor. The tank is contained within the bedplate; and by making it a feed-water heater, a great saving is effected. The engine is strong, and all the parts are easy of access.

"A corn-dressing machine, fitted with a patent screen, is exhibited by R. & J. Reeves, of the Bratton Iron Works, Westbury, Wilts. This machine combines a blower, a riddle, and a screen, and the sample obtained at one operation is equal to that of other dressing machines after undergoing the subsequent process of screening. The corn is fed from the hopper in a thin stream before the blast, so that the wind has full power to carry to the tail all light corn; after passing the wind the corn falls on the riddle, which takes out all large substances and 'whitecoats;'

then dropping on the patent screen, the small corns and seeds are taken out. These screens are made of perforated zinc, with different sized holes. The surface of the screen, in lieu of being flat, consists of a series of longitudinal ridges and furrows; the corn enters at one end, and is shaken from side to side of the ridges by the motion of the machine, and thus a large screening surface is obtained. The holes are kept clean by strips of iron hung under the ridges, which, by the motion of the machine, prevent the corn from stopping the holes, and so keep the screen clear.

"J. Patterson & Co. (Limited), Beverley, exhibit several of their compound action mills, already illustrated in our pages. These mills, although of recent date, have already attained a wide notoriety, which speaks well for their practical utility. Owing to the peculiar and very simple arrangement of the grinding surfaces, they are both crushing and grinding mills. They will split beans and crush oats, gorse, locusts, &c., in a most effective manner, and will, without any change or alteration of parts, grind wheat, barley, linseed, cotton seed, &c., to meal for feeding purposes, even when the grain is in too bad a condition for grinding in other mills. A bone-dust mill on the same principle is also here exhibited.

"Some of the most useful articles in the Show are to be found at the stand of Alfred E. Peirce, of Hammersmith, who exhibits a variety of galvanized metal articles in the shape of feeding troughs, wheelbarrows, water tanks, piggeries, and pumps. The feeding troughs are constructed wholly of wrought iron, with turn-over edge and smooth surface of equal strength throughout, thus avoiding dangerous keen edges and numerous rivets, and as the trough is galvanized after it is made, all leakage is avoided, and the joints thoroughly protected. The wheelbarrow, composed entirely of galvanized iron, a great portion of which is tubular, not only presents a light appearance, but is in reality light. The arms of the wheel and the frame are tubular, the latter consisting of two bent tubes extending from front to rear, and forming not only the supports for the wheel, but also the legs and handles. Another article is a universal drinking trough, cattle-crib water cart, garden or fire engine, or dipping apparatus. The body of the cart, constructed on the trough principle, is mounted upon

three wheels, with turn-over shafts and covers, loose hay grid, and watering spread with rotatory or lever pumps for ordinary pumping, and jets to throw a continuous stream of twenty gallons per minute to a height of fifty feet. This is really a *multum in parvo*, and should be seen to be thoroughly appreciated. The piggeries and kennels are also constructed wholly of galvanized wrought iron. The framing of each is of angle iron, secured to tubular hinged pillars covered with corrugated iron, to fold for transit, and to enable a labourer to fix or take down in a few minutes at pleasure. The pumps are mounted upon a tubular wheel and barrow frame, precisely similar to the wheelbarrow, are light and easy of transport, and are entirely self-contained. They are useful either as ordinary pumps, or as fire or garden engines.

“A simple, cheap, and efficient portable farm railway, with truck and turntable, is exhibited by the inventor, Mr. John Grant, of Linton, Kent. The object of Mr. Grant's improvements is to supply a cheap but thoroughly practicable tramway system for the use of farmers in carting manure and farm produce over their land. The portable railway consists of light wrought-iron rails, secured to longitudinal wooden sleepers, to the ends of each of which, on the underside, there is secured a plate of sheet iron, which at one end forms a projecting tongue, and at the other end a socket, to receive the corresponding tongue on the adjoining end of the next rail and sleeper, which is readily slipped into its place by a boy, and requires no fastenings, as the weight of the truck in passing over the joint nips the tongue in its socket as in a vice, and leaves it free again to be removed and replaced for forming a second track as soon as the train has passed. In manuring a field on this system, the second track would be laid parallel to the first and about two rods removed from it, and so on throughout the width of the field, the different tracks being connected by a cross track and portable turntables of very simple construction. There is much that is worthy of commendation in Mr. Grant's system, which has already been in operation in various parts of Kent, and has given great satisfaction. As a saving in draught power, it is decidedly a step in the right direction. We refer such of our readers as may be interested in knowing more about Mr. Grant's portable railway

system to a paper read by that gentleman before the Maidstone Farmers' Club in January, 1864."

85. *Steam Cultivation*.—On this important subject we take this and the following article from "Engineering:"—(a) "More than thirty years ago Mr. Heathcote, aided by Mr. Josiah Parkes, took out a patent for cultivating machinery, and a plough made in accordance with this patent was tried at the Dumfries meeting of the Highland Society, in 1837. The results obtained with it, however, did not, in the judges' opinion, justify the award of a premium. Twelve years later, in 1849, a steam plough was brought out by Mr. Hannam, of Berkshire, and this apparatus, which was constructed by Messrs. Barrett and Exall, may be regarded as the first in which wire ropes, leading from an ordinary engine, were employed to work a set of ploughs. Still later, Lord Willoughby d'Eresby applied steam power for cultivating purposes on his farms in Lincolnshire. His engine was placed in the middle of the field to be ploughed, and the ploughs, which were attached to an iron frame, and made so that they could be reversed at each end of their travel, were drawn backwards and forwards between the engine and anchors fixed at each headland. His Lordship sent to the Great Exhibition of 1851 a detailed plan of his mode of using steam power.

"Shortly after this the Marquis of Tweeddale introduced another improvement; two engines, one placed on each headland, were employed in his system, the ploughs being drawn to and fro between them. About the same time a rotary cultivator was devised by Mr. Usher of Edinburgh, which was tried several times with more or less success, but was ultimately laid aside.

"In 1858, on the occasion of the meeting of the Royal Agricultural Society at Chester, the Society's premium of £500 was awarded to the late Mr. John Fowler for the system of steam cultivation introduced by him, his competitors being Messrs. Howard of Bedford, Mr. Thomas Rickett, of Buckingham, and Messrs. Crowley and Sons, of Newport Pagnell. The practical introduction of steam power for cultivating purposes may be considered to date from the Chester meeting, as since that time its use has extended rapidly.

"At the Chester meeting Mr. Fowler employed one of Ransomes and Sims' engines, of 10 horse power, driving a separate

windlass, the latter being made by Messrs. R. Stephenson and Co., in accordance with a patent taken out by Mr. Fowler and Mr. Wm. Worby, in December, 1857. The engine and windlass were shifted along one headland, and an anchor along the other as the work proceeded, an endless rope passing round friction-drums on the windlass, being employed for drawing the ploughs backwards and forwards. In perfecting a system of steam cultivation, there are numerous obstacles to be overcome, and we accordingly find that many plans were tried by Mr. Fowler before he adopted the system now so well known. At first the engine and windlass were placed on one side of the field to be cultivated, and the wire rope was led from the windlass to a pulley fixed in the corner of the field, thence, round a movable anchor traversing along one headland, across the field to an anchor moving along the opposite headland, from which it returned round a fixed pulley at the corner of the field to a second drum on the windlass. The ploughs were attached to the rope between the two anchors, and were traversed backwards and forwards by winding the rope on and unwinding it from each drum alternately. An improvement was next made by removing the fixed pulleys from the corners of the field, and allowing the rope to pass diagonally from the windlass to the movable anchors; the rope immediately after leaving the drums being led over a pair of horizontal guiding pulleys attached to the windlass. The next modification was the application of a direct pull upon the implement, the winding drums being placed underneath the engine, which was itself made to travel along one headland, whilst the rope passed over a sheave carried by an anchor, which was shifted along the opposite side of the field.—The ploughs were of course hauled to and fro between the engine and anchor.

“Then followed an important improvement, the employment of an endless rope, stretched across the field like that just mentioned, but driven by friction instead of being alternately wound on and unwound from a drum. At first, as in the trials at Chester, the rope was led four times half-round two grooved pulleys, in order to get the necessary amount of hold upon it; but it was found that this plan, although it worked well when new, had faults which ultimately led to its abandonment. Considerable injury was done to the rope by the numerous bends, and it was

found in time that the grooves of the driving drum wore very unequally, those first receiving the rope wearing twice as fast as the others. The drums thus became of different diameters in different parts, and a continual surging of the rope was the necessary result. A single driving drum with two V grooves, in each of which the rope was made (by means of guide pulleys) to take three-quarters of a turn, was next employed; and this form of driving gear, though possessing to some extent the disadvantages of that last described, is still at work in some places. The contrivance of the 'clip drum' at length placed at Mr. Fowler's disposal a means whereby the rope could be driven with only a single bend, without slip, and consequently almost without abrasion. This clip drum which is now so extensively used in steam ploughing machinery, and is also employed to some extent for the winding pulleys of colliery inclines, consists of two rings carrying between them a series of pairs of clips, the jaws forming which are so hinged to the rings as to form a V, in which the rope is laid; the strain upon the rope tending to close the clips and make them grip more tightly. Each pair of clips closes as it arrives at the point at which the pressure of the rope commences, and opens again after passing round to the point at which the pressure is removed. The adjustment necessary for ropes of different sizes is effected by the lower ring being screwed upon the main cylinder of the drum, so that by turning it round the distance between it and the upper ring, which is made in one piece with the body of the drum, can be varied.

"When two drums, on each of which the rope is alternately wound and unwound, are employed, the tightening of the rope is ensured by driving the winding-up drum at a slightly greater speed than that from which the rope is being given off. The slack is thus taken up by a few revolutions of the drums, after which the pulley driving the paying-out drum slips on its shaft, it being connected with the latter by a friction-brake. When an endless rope is used, the tension is maintained by a simple arrangement of 'slack gear,' carried by the plough. It consists of two small barrels to which the rope is attached; these barrels being geared by pitch chains and pulleys, so that the unwinding of 1 ft. of rope from one barrel winds up 5 ft. upon the other, and *vice versa*. The pull of the engine upon the implement is

received by these barrels alternately, and as the tension on the rope leading from the pulling barrel is always five times as great as that on the following rope, the apparatus is enabled to adjust the length of the rope to the width of the field being ploughed. This will be more clearly understood if we suppose the anchor to be moved farther from the engine, as it would be by an increase in the width of the field. The effect of this would be, that a certain length of rope would be unwound from the following drum, and one-fifth of that quantity would be wound up upon the drum receiving the pull, the implement being advanced through a distance corresponding to the length of rope thus wound up, and this motion being in addition to that given by the engine. If the anchor is moved towards the engine by the narrowing of the field, the reverse operations of course take place.

“The slack gear is essential in order to maintain the rope clear of the ground, and it also gives to the rope a certain amount of elasticity, and enables the implement to better adapt itself to the irregularities of the field. At first considerable trouble was caused by the rapid wear of the ropes, which were made of iron wire. They were found to only do about 200 acres before being worn out; the miles run being about 750, and the cost 1s. 7d. per mile. In 1857, ropes made of steel wire were introduced; the first used being, we believe, made in Birmingham by the late Mr. Webster. These were found to work admirably, the first rope running 1,800 miles, and costing 1s. per mile. At the present time, the improvements in the driving-gear and in the machinery employed for keeping the ropes tight, enable the steel ropes to be run on the average 9,000 miles, the cost being $2\frac{1}{4}$ d. per mile. The rope generally employed is $\frac{1}{8}$ in. in diameter, and weighs about 2 lb. per foot. Its cost is about £84 for a length of 800 yards, and it will accomplish the cultivation of from 2,000 to 4,000 acres, according to the nature of the ground, and width of the implement employed.

“In the last system of steam-ploughing machinery, introduced by Mr. Fowler, two small engines of 7 or 8 horse-power, one traversing along each headland, are employed instead of the larger engine and movable anchor adopted in the plan last described. Two engines, placed one at each end of the furrows, and each alternately hauling the set of ploughs or cultivators towards it-

self, were employed by both Mr. Howard and Mr. Fowler in 1863, the improvement just alluded to being that the engines are connected by an endless rope, attached to the implement, and passing round the clip drums of both engines, which haul upon it simultaneously. Each engine thus acts as an anchor for the opposite one, or, in other words, each engine alternately hauls directly upon the rope leading directly from the implement and upon the slack rope leading from the drum of the other engine. A pair of engines thus arranged were exhibited at the meeting of the Royal Agricultural Society, held at Newcastle in 1864. Each of the engines was of 7 horse-power, had a single cylinder, and was fitted with locomotive action and steering gear. They ploughed at the rate of eight acres per day of ten hours, driving four furrows $6\frac{1}{2}$ in. deep at one time through a strong loam soil. Three men and two boys were engaged in attending to the apparatus; and the consumption of fuel was 188 lb. per acre. Although the plan of using two small engines in place of one large one, involves a slight additional outlay, it possesses advantages which will no doubt lead to its adoption in many cases. The engines being smaller are better adapted for the general work of the farm, and being lighter they can be moved about more readily. Both lines of the rope are also in a state of tension, and they can thus be carried by a less number of rope porters. The cost of a 14 horse engine with the necessary anchor and cultivating machinery is a little less than £1,000, whilst that of the two 7 horse engines with the accompanying implements is about £1,140. In the first case, two men and three boys, and in the latter, three men and two boys are required to attend to the machinery.

“In addition to the systems already described, we must mention those of Messrs. Howard, of Bedford. Some of their machinery is arranged on the principle of Mr. Smith, the ordinary portable engine used being placed in a corner of the field to be ploughed, or in an adjoining field or road, and connected with the windlass by an universal joint or leather driving band. The rope, after leaving the windlass, is led over guide pulleys, arranged in a manner resembling that first adopted by Mr. Fowler, and which has been already described. The advantages claimed for this system are, that it is cheap, and that the engine can be placed

on any hard ground that may be available. Messrs. Howard also employ, as has been already stated, a pair of engines traversing the opposite headlands of the field to be ploughed, and hauling the implement backwards and forwards between them. The same firm has also introduced a new form of winding engine carried upon three wheels, and having the boiler placed across the frame, or at right angles to the usual position; and they claim for this engine several advantages, one of the principal being that the water-level in the boiler is but little disturbed even when the engines are being worked up heavy inclines.

“Even now that steam cultivation has been so extensively adopted, it is difficult to make any satisfactory estimate of the cost incurred by the different systems, as compared with that of horse labour. The difference in the state of the land, the size of the fields, and the situations in which the machinery has to be placed, cause the cost of steam cultivation to vary from 2s. 6d. to 20s. per acre; but there is now no doubt but that, except on those farms which are divided into a number of small fields, steam power can be applied with very economical results. The headlands are not ploughed, but the land thus left uncultivated does not amount to more than about half an acre in a field of 20 or 30 acres. A distance of from 300 to 400 yards between the headlands is found to be the best adapted for the profitable working of the apparatus. In addition to its reduced cost, steam cultivation has many other advantages. The hauling power which it is possible to apply to a plough worked by four horses, is not more at the utmost than about 70 lb. per inch in width of the soil acted upon; but with steam, a power of from 70 to 280 lb. per inch in width can be applied, and as the implement is moved through the ground at a much greater speed, the land is much more thoroughly broken up. The hardening of the ground occasioned by the walking of the horses over it is also avoided, and the strain upon the implement is consequently less. The fear that the steam plough could not be used upon stony lands has proved to be groundless, the apparatus having been worked on a stony soil, where it had to tear up 20 tons of stone per acre, without receiving any material injury. Abroad as well as at home the steam plough has done good work, and in Egypt especially large numbers have been employed. We have, in the pre-

sent notice, by no means exhausted the subject of steam cultivation, there are many points connected with it which ought to be enlarged upon, and many details which remain to be described."

(b) "During the past three months (dated January 5th, 1866) a most active, although not unpleasant, controversy has raged, in the agricultural press and elsewhere, as to the relative merits of Fowler's and Smith's systems of steam cultivation. Mr. Simon Hutchinson, a farmer near Grantham, had published a comparative statement to show that the respective systems had been tested with the following results:—

	FOWLER.	SMITH.
Total First Cost . . .	£1,378	£500
Engines	2 of 14 h. p.	1 of 10 h. p.
Width of Cultivator . .	6 ft.	3 ft.
Number of Tines . . .	7	3
Days Employed . . .	125	127
Acres Cultivated . . .	691	773
Acres per Day	5½	6
Whole Cost of Working	£504	£264
Cost per Acre	14s. 7d.	6s. 10d.

"Such a comparison was certain to go home to all the interests represented by steam cultivation—to the makers and purchasers of steam ploughing machinery as well as to those who let it out for hire and those who take hirings; and, beyond these classes, a great number having only a general, or possibly a scientific interest in the matter, would wish to see such a striking contrast fully explained. The avowed object of the tabular comparison was to enlist the 'thoughtful consideration of agriculturists'—in other words, to enable them to pronounce a general verdict upon the relative merits of the systems compared together. The whole controversy to which the comparison has given rise (and in which Mr. Smith took a very prominent part, although Messrs. John Fowler and Co. did not apparently take any) has been reprinted by Messrs. Fowler and Co., a circumstance which we may note, in passing, would appear to show that their firm considered that they had the best of it in the end.

"Mr. Hutchinson gave his own experience with Smith's tackle, on his farm, Dunton Lodge, Beds, where he reports the stiffest clay soil, worked twice over, the first cultivation being to a depth of 7 in., and the succeeding operation to a depth of 10 in. All

the work with Smith's tackle was upon one farm. The Fowler apparatus, it appears, made only one cut through the ground, and that to a depth of a foot or more, the land being understood, also, to be heavy. But the 691 acres set down to it were comprised in forty-eight different farms, between which the engines had to travel no less than 248 miles, so that the comparison, upon a further examination, is not one applying to like conditions of working ; indeed, for the purpose under consideration they were most dissimilar. Again, the reported 773 acres worked by Smith's tackle were measured upon a farm map, without deduction for fences, ditches, &c., and Mr. Hutchinson himself afterwards consented to a corrected area of $734\frac{1}{2}$ acres ; whereas, from what we can see in the published correspondence, the 691 acres set down to Fowler, were actually and fully covered. Had Smith's tackle, with a portable engine, been moved 248 miles in working upon forty-eight farms, a number of horses would have been necessary to move it—Mr. Hutchinson's opponent says as many as twenty-eight in some cases, whereas Fowler's locomotives always fought their way out without help, even when sunk three feet deep in an old culvert or in a bog hole. If, on the other hand, a locomotive were employed with Smith's tackle, the first cost and repairs would be largely increased. Altogether the comparison of Mr. Hutchinson is not a fair one, irrespective of any consideration of either system of steam ploughing. It is unfair because the circumstances in the two cases were widely different.

“The balance of evidence, so far as published, is, however (as was to have been expected), against the alleged cheapness of Smith's system as compared with Fowler's. Many gentlemen, large cultivators by steam, have written to the agricultural papers, giving a totally different experience. One gentleman, Mr. Joseph Nicholls, of Queen Camel, Somerset, and who observes that ‘he is about the largest proprietor of steam cultivating machines in England,’ states that he has two of Fowler's large sets of engines and tackle constantly let out at 20s. an acre, where six or seven of Smith's, in the same neighbourhood, are scarcely ever hired, although let out at 6s. per acre. And Mr. Nicholls further says, that in the twenty-five working days of last September, he cultivated (not ploughed) exactly 225 acres of stiff clay land, or 9 acres per day, to a depth of from 12 in. to 18 in., and this, too, upon land that

had never been steam ploughed before. Mr. Smith has raised several points, but none which appear to overthrow the great mass of public and private testimony now printed by Messrs. Fowler and Co., and to the effect that their large apparatus can plough from $5\frac{1}{2}$ to 9 acres of stiff land per day, or cultivate nearly twice as much more, and to a depth of from 8 to 12 in., at a cost for ploughing, of from 5s. to 10s. per acre; the cost for cultivation being much less. Sufficient time has elapsed to thoroughly establish the fact that the working of such apparatus is not only much cheaper than horse-cultivation, but that it is largely preferred to other plans by experienced purchasers."

86. *Agricultural Engines*.—"A very great improvement," says "Engineering," "in the general construction and details of agricultural engines has been made with the gradual increase of the steam pressure at which they are worked. It is not very long since many portable engines had cast-iron crown bars on the fire-box, and we have seen many old fire-boxes which had gone down 2 in. or more at the middle of the crown. The stay bolts are now pitched more closely than formerly, and the general character of the boiler work is more thorough and accurate. The makers, with the increase of pressure, have had to find harder mixtures of iron for their cylinders, and we have given, in former numbers, several of the mixtures employed, one of the latest and most promising being that of two-thirds hematite No. 1 to one-third of Bessemer steel. It is now customary with several of the best makers to surround their cylinders with a steam jacket, and in some cases this is made the channel through which the live steam reaches the valve box. In this case the jacket needs to be well blown through with steam when the engine is new, to prevent any sand, adhering to the inner surfaces of the jacket, from being carried through into the cylinder. For portable engines single cylinders are now more commonly employed than a pair, and the former involve less attention in working, and fewer repairs. Yet there are many who like the pair of cylinders, we cannot quite say for what reason, unless it be the slight advantage of having no 'dead centres,' and it is the fact, moreover, that the pair of cylinders cost but about £30 more, at the outset, than a single cylinder, taking the case of an 8-horse engine. The cylinder now has a longer bearing upon the boiler than formerly,

the seat of the cylinder extending past the flanges at each end, and being secured by additional bolts. In the best practice, the bolts which fasten the cylinder to the boiler are gradually enlarged for a short distance under the head, and the hole in the boiler is rimmed out to a corresponding form, so that the bolt, put through from the inside of the boiler, is tightened by the act of screwing up. With this slight precaution the leakage of steam from the bolt holes through the boiler is now very rare. The piston rings of cast-iron should be cast from the same metal as the cylinders, and be cut open at one point only. If a pin be fixed in the edge of one, and a corresponding hole be made in the edge of the other, to keep the joints at right angles to each other, the rings are apt to get broken at the hole and pin respectively. Nor is the maintenance of the joints, at right angles to each other, of any real importance in preserving the truly circular bore of the cylinder, nor in preventing the leakage of steam. The joints or openings of both rings may coincide, and instead of a V wedge to set them out, a cylindrical tightening piece of gun metal will effect the same purpose with less stiffness in working and without any risk of working through and scoring the cylinder. It is now usual to give to the piston and junk ring the full diameter of the bore of the cylinder when new, but care must be taken that the piston can never so far override the shoulder, formed near the ends of the cylinder, in counterboring it, as to allow the junk ring to drop and jam there.

“Many portable engines are now made with traction gear, and are known as traction engines, yet of these it is probable that nine-tenths are still really employed for the ordinary purposes of portable engines. Only a very few traction engines are regularly working, for the purposes of traction, in the whole kingdom. The farmer or contractor can purchase an 8-horse portable engine for £230, but for £360 he can now purchase an 8-horse self-propelling and traction engine, and the extra strength and real power of this makes it really equal, for driving pumps or machinery, to a portable engine costing £280, so that only £80 may be said to be paid for the self-propelling gear, and with this the engine can always go almost anywhere without horses.

“The construction of traction engines requires much more skill, and greater strength of parts, than that of ordinary portable

engines. One of the most prevalent mistakes at first made, was in having too quick gearing, and too light driving axles, crank shafts, and driving gear generally. The leading makers are now using $5\frac{1}{2}$ inch best hammered scrap driving axles for 12-horse engines, gearing down to one revolution of the driving wheels, to every 13 or 15 revolutions of the crank shaft. The crank shafts are about $3\frac{1}{4}$ in. in diameter, and although they are not often made of Lowmoor, the very best makers obtain a material which appears to be quite as good, and much cheaper, from a Northampton ironmaster, now well known in the trade. For gearing from the second motion shaft to the driving wheel, the pitch chain is now very extensively used, and with great success. But this is only the result of the very best construction. The links are now cut from a 2 in. square bar, then planed on one side, drilled, and the ends rounded, and steel pins driven in. Each link of the proper construction weighs 7 lb. The small pinion is of cast steel, or six tooth, shrouded to take the bearing of the chain over its full width. The larger wheel is of great strength. In Mr. Aveling's practice, it is made 2 in. thick, and stiffened by stout ribs, and, as soon as it is cast, cold water is run for a long time through the central core, so that all parts of the large chain wheel may cool equally fast and without strain. The teeth, one to every other link of the chain, are chilled, and the centre of the wheel is bored, and the driving axle turned truly cylindrical, and two $\frac{7}{8}$ in. or 1 in. square keys are employed for fastening. With this amount of care in construction the chain wheels never break. The pitch chain, however, becomes more or less slack with wear, and there is one ready means of tightening it introduced by Mr. Aveling, and now adopted by some of the other makers.

"Traction engines all require the link motion as a means for instantly reversing, and in addition to the opportunities it affords for expansive working. There are more than one maker of portable engines who have not given the attention to the link which it deserves, and their engines beat very unequally. The position of the weigh shaft and the point at which the weigh link is attached to the slotted link have most influence perhaps upon its action. The weigh link should be attached to the slotted link near the curved centre of the slot, whether the link

be held at its mid length or no. We cannot, in an article like this, enter upon the whole mode of laying out the link motion, but for those who have not yet mastered it, the best course may perhaps be to work out the best positions upon a model, so arranged that all the centres can be readily shifted. The objects are, of course, to admit steam for, as nearly as possible, equal portions of the double stroke, to exhaust equally on both strokes, to obtain these requisites at all the different grades of expansion, and to diminish, as much as possible, the slip or block of the link. When all is done, allowance must be made, in fitting the valve gear in the ordinary manner to the boiler, for the expansion of the latter when heated.

“The use of expansive gear, and generally greater care in the working of the steam in portable engines, has enabled smaller fireboxes than were formerly required to produce steam sufficient for a given power. The fireboxes of 8-horse engines are not commonly much, if at all, larger than those of the 5-horse engines made some years ago.

“It should be even more widely known than perhaps it is that traction engines are now working in almost all parts of the kingdom, and that when sent from the makers to the purchasers, at distances of even 100 to 500 miles, they always go on their own steam. They work both up and down inclines as steep as 1 in 6, and often go over ground where horses would sink. They are employed in the Government dockyards, and by the large engineers, for hauling weights up to 40 tons, and we last week gave an account of the removal of the great block of Cornish granite, intended for the base of the Wellington memorial at Strathfieldsaye—a total load of 40 tons hauled for some miles by a traction engine. For ordinary farm work, especially for steam ploughing, much less tractive power at the driving wheels is required, and indeed many of these engines are constructed with the intention only that they shall be self-moving. When we consider that but a very few years ago an outlay of from £1,000 to £1,500 was considered necessary for a good traction engine, it is a great deal that for less than one-half of even the smaller of these sums, engines, capable of working up to 40 indicated horse-power, can now be had, and which perform all that has been above mentioned. We cannot but think that with so many

of these engines now at work, the time is not distant when some of the present restrictions upon the use of steam upon common roads will be removed."

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION ELEVENTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

Portable Engines,—Engineering, July 20th.

Portable Engines,—Engineering, June 22d, July 13th, and July 27th.

Portable Engines,—Engineer, June 15th, and July 6th.

Chaplin's Traction Engine,—Engineering, May 4th, Illus.

Steam Plough Companies,—Engineering, March 9th.

Howard's Agricultural Engines,—Engineer, Jan. 26th., p. 64, Illus.

Mechanical Exhibits at the Bath and West of England Society,—Engineer, June 8th, p. 409, Illus.

Steam Cultivation,—Engineering, Nov. 16th, p. 379.

On Drying Grain Artificially,—Engineer, Nov. 2d, and 16th, Pp. 329, 373.

Portable Engines,—Mech. Mag., Nov. 9th, p. 285.

DIVISION TWELFTH.

MISCELLANEOUS.

Engineering, Past, Present, and Future, by John Imray, Esq., C. E.; from the "Scientific Review" of April, 1866,—“But a few years have elapsed since engineering began to be recognised and followed as a regular profession. At a period so recent as the end of the last and the beginning of the present century, the greatest engineering works were planned, and the most important mechanical improvements were devised, by men not educated as engineers, nor even experienced in the business to which circumstances called them. When a want was felt, or when a work had to be done, men of sound practical sense, and of a mechanical turn of mind, appeared, and, having their minds turned in this particular direction, planned and originated new enterprises, which have been carried by their successors far beyond the most sanguine dreams of the originators. Some of these men were endowed with genius of the highest order, for in those early days

of engineering they had no experience to guide them in their calculations, they had few tools to carry out their designs, they had scarcely materials on which to operate; and yet they contrived in many instances to execute what may bear comparison with the best works of the present time.

“In the early days of engineering, as in those of other arts and callings, division of labour scarcely existed. The old-fashioned millwright had to construct the apparatus for obtaining, as well as that for utilizing power, in all their various modes and applications; he had to lay out the water-course for the mill, or the tram-road for the mine; he had to build the bridge, the lighthouse, the quay; to plan and execute the turnpike or the canal. He was believed to be a man possessed of some peculiar illumination, that enabled him to deal with inert matter in ways inconceivable to the uninitiated. He was even suspected of witchcraft, or magic; and until an era of enlightenment came to sweep away such delusions, he could scarcely venture to carry out the suggestions of his genius in the face of popular superstition. And who shall say that such men as Watt, Telford, and Stephenson were devoid of some peculiar illumination that made them, more than their contemporaries, the masters of those materials and forces which they have left bound as slaves to do the work of their successors?

“Instead of a few great men standing out in bold relief as engineers amid millions who regarded all things relating to matter and force as profound mysteries, there are now thousands who creditably profess, and tens of thousands who pretend to, engineering. And, as might be expected where the objects are so various, manifold divisions and subdivisions in the profession have manifested themselves. The term civil engineer, originally applied to all not engaged in military engineering, appears now to be restricted to those who work on the larger scale, leaving the title of mechanical engineer or machinist to those who confine their attention to apparatus, machinery, or mechanism. And each of those classes is subdivided according to the peculiar nature of the works which their professors undertake. In the former are mining engineers, railway engineers, and those who confine themselves principally to canals, docks, and other tide-works; while in the latter are the makers of land engines, of marine engines, and of locomotives.

tives, the constructors of tools or apparatus to be used in making other apparatus, and of the firm machinery used in various arts, as well as those who are millwrights, as of old. The agricultural implement maker has now become an engineer, and justly so, since agriculture has become a mechanical art as much as cotton-spinning or paper-making.

“It may be interesting to inquire into some of the causes which have produced so vast a change in the engineering world in so brief a period. The proximate of these are, without doubt, the enormous extension in late years of mechanical knowledge, and the vast accumulation of inventions by which that knowledge has been brought to bear upon the manifold wants of life, and even to create and supply new wants. But if it be asked why such knowledge has been so widely and rapidly diffused, and wherefore inventions have crowded on each other's heels, it may, perhaps, be answered with truth that it is primarily owing to two great steps that were made within the past century, and which will doubtless mark the stride of progress for centuries to come. Those steps were—

“1. The production of the Steam-engine in a practical form by Boulton and Watt, and

“2. The creation of the Iron Manufacture by Cort and others.

“If the mind could for a moment conceive the world in the middle of the nineteenth century without the steam-engine, and therefore devoid of all the arts and appliances which this mighty power has created, the vast importance of the invention might be in some degree appreciated. No steam-vessels, no railways, no manufactures of importance; scarcely any mines; great towns (if great towns could exist) starved by irregularity in supplies of meat and drink; agricultural produce at home far behind the wants of the population, and the supplies from abroad uncertain and long delayed; dear clothes; dear paper and printing, and consequently few newspapers and books; travelling tedious, dangerous, and expensive, in time as well as in money; communication of intelligence scanty and slow; and, as one of the consequences of such a state of things, intelligence cramped, prejudices strengthened, ignorance and misery the common lot. And, in like manner, if the iron manufacture were supposed to be suppressed, or never to

have existed, how different at this moment would be the condition of England and of the world !

“Those two great strides, though made independently, were truly made in concert, and each was necessary to the other. For want of iron suitable to his purpose, and the means of working it, Watt was limited in the power and applications of his engine ; and but for the engine, the power which it conferred, and the demand which it occasioned, there could have been neither the means nor the motive for the iron manufacture. Given, then, these two great inventions, perfected about the time when the civilized world began to rest from a long series of bloody wars and revolutions, during which the great labouring masses had made their voice to be heard and their strength to be felt, and the rapid progress of the mechanical arts since that period may be understood.

“Some kinds of living creatures appear to have the power of reproduction by division and subdivision. An individual divides itself into two, each a perfect creature of its kind, and each again divides itself, and so on without limit ; and thus, after comparatively few generations, the number of individuals becomes very great (a million after less than twenty divisions). Such, in a remarkable degree, may be said to be the character of mechanical inventions, except that, perhaps, their reproduction proceeds by divisions into dozens and scores rather than into pairs, and that their number increases with proportionately greater rapidity. Take, for instance, the electric telegraph itself, as applied to practical purposes, a descendant, collaterally through the railway, from the great parent steam-engine. For years the germ of this invention floated in the brain—perhaps in many brains. It even presented itself, in the larva stage, as it may be said, as an interesting toy at public exhibitions, and so for years it lay comparatively neglected and forgotten ; for men did not then require to have themselves and their goods rapidly conveyed from place to place, and therefore did not so much need rapid conveyance of intelligence. While it lay in the embryotic form the London and Birmingham Railway was extended from Camden Town to Euston Square on a gradient which was too steep for the locomotives of that period. The trains were pulled up this gradient by a rope worked by stationary engines at Camden Town, and signals for

the starting and stopping of those engines were transmitted by a water-pipe fitted with a piston, so arranged that by depressing the piston at one end, the water-level was altered at the other; and, at the same time, the air expelled from the tube sounded a whistle to call the attention of the engineer to the signal. The writer of these paragraphs had frequently to attend to the management of the engines according to those signals, and shortly afterwards he was employed in the preparation of the machinery for working the Blackwall Railway by rope traction. The drawings of the Blackwall machinery were almost daily under the inspection of the engineer of the line, Mr. Robert Stephenson, who, being one day asked how he proposed to signal for the working of the engines over the $3\frac{1}{2}$ miles of line, replied, almost prophetically, that he had not quite made up his mind, as that it could be done by water, as at Camden Town, but that he was convinced something better, probably some electrical arrangement, would be devised before the machinery could be ready for action. And true it was that, before those engines were started, an electric telegraph was fixed on the line, and answered the purpose most completely. It is not yet a quarter of a century since that incident occurred, and who shall count the inventions made and patented, and the still more numerous inventions never perfected or patented, that have sprung from that rude germ which slumbered in the Adelaide Gallery, and from the successive divisions and subdivisions of its more highly organized offspring?

“While mechanical inventions thus multiply, extending their feelers into all branches of science, and yielding their aid to all the arts of life, and, unhappily, to those of death also, the calling of an engineer becomes one that demands the most varied knowledge, the most versatile talents. The engineer is, truly speaking, the man who turns crude matter into forms and combinations such as render it suitable to human use, whether he bore into the crust of the earth, tunnel its mountains, fill its valleys, dam its rivers, and stem the tides of its ocean, or whether he fashion its products into stable structures or into quick-moving machinery, to bear men, their goods, their intelligence from place to place; to grind their corn, to spin their cotton, to print their newspapers, to take as well as to defend their lives. The pursuits of the engineer are lofty, because they are extensive and

useful; and they are ennobling, because they demand the highest intelligence and the widest knowledge. What the mathematician solves with imaginary forms and symbols, the engineer works out with actual material things; what the astronomer investigates as exhibited in celestial phenomena, the engineer practises with terrestrial objects. The philosopher and the man of science observes, collates, compares, generalises, and reasons up from consequence to cause, and from proximate cause to causes more remote; the engineer takes the results arrived at by the philosopher, accepts his laws, and puts them in force in new circumstances and under new conditions. The philosopher may demonstrate the existence of those laws to which all natural phenomena are subject, but it is for the engineer to put the yoke on Nature, and make her work a willing slave to those who know how to control her.

“The engineer is, however, by no means tied down to the exercise of mere knowledge or judgment, to the application of hard, dry, ascertained facts only; he must, in an especial manner, exercise one of the highest, if not the very highest of the mental faculties, that of imagination. The mechanical draughtsman sets before him a sheet of clean paper, and gradually upon that sheet there grows a true picture of some apparatus existing as yet only in the mind of the inventor. But before one line or one curve could have been traced there, the archetype of the work or of some of its principal features must have been in the draughtsman's brain. He must have seen in his mind's eye his wheels revolving, his levers vibrating—nay, invisible fluids pressing, expanding, or condensing—and his drawing is merely the first representative embodiment of that which ideally existed, and which has to be yet further developed in its final material form.

“When the mathematician has to solve a problem, he can generally represent the conditions by some recognised symbols, and operate upon them according to some well-known rules; and when the problem eludes the grasp of his known and established symbols, he has, though rarely, to invent some new calculus which shall bring it under his control. But the engineer, while he has indeed certain well-known mechanical elements and combinations to deal with, must be ever ready to invent some new calculus applicable to the special cases that are presented to him; and

sometimes out of principles apparently barren and void, he has to elaborate a most complex and efficient system of action. What, for instance, can appear at first sight so poor in useful matter, so little capable of producing complex results, as the fact that a current of electricity maintained across a bar of iron renders it magnetic? And so, when the electric telegraph was in its infancy, men thought only of multiplying signals by multiplying wires and magnets. Then, perhaps, they thought of recording the signals, for that force which could produce a motion visible to the eye could certainly be made to leave a mark on paper. Suddenly, a new means of distinguishing symbols came into view; a signal might be visible for a longer or a shorter period; it might leave a longer or a shorter stroke on paper moving under its marker. Thus, dots or strokes might be produced, and having dots and strokes which could be combined in any order and in any number, all conceivable symbols could be represented by the action of one wire and one magnet. Electro-magnetism was a new calculus applied to the transmission of human thought, and the dot and stroke was a newer calculus applied to the solution of problems presented by telegraphy.

“Looking to the vast advance which engineering, in the widest sense of the word, has made of late years, and the enormous field over which its results are spread, it may be difficult to conceive the possibility of proportionate advances hereafter. Within half a century men have learned to combine the elements of the ancient world so as to furnish a force unlimited in its intensity, versatile in its applications, and under absolute control for the most minute operations, as for the most gigantic efforts. By combining mineral fuel with the air we breathe, the fire acts upon the water, and the result is that vast power of steam which has so far changed, and is still changing, the face of the world. In spite of winds and waves, the products of the most diverse climes are rapidly and safely exchanged, and the inhabitants of the most distant lands communicate with one another, and intermingle without delay and with little danger. Over hill and valley, through mountains and across rivers, passengers and goods travel with almost the rapidity of a bird, and with so little peril, that it is positively twenty times safer to travel constantly by railway than to walk the streets of the metropolis. The finest fabrics are woven by shuttles

worked no more by hand, and even the most delicate thread is not only spun, but is laid in its right place in the pattern by steel fingers more delicate and infinitely more certain and rapid than those of the Indian who devotes a lifetime to the production of a single shawl. The refuse of the loom, and fabrics worn past use, are reduced to pulp, and every fibre is placed among its fellows and knitted to them, so that broad and continuous webs of paper stream from the loom, and these are scarcely touched by human hands, till they issue in millions of sheets from the printing machine, to carry information and instruction over the face of the earth. Mines are pumped dry, and their produce raised from depths of many hundreds of fathoms—rivers of water are sent daily into cities—fields are ploughed—furnaces are supplied with air-blasts—metals are forged, rolled, cut, turned, planed—corn is ground—all works that are necessary to human life, and many that are superfluous or injurious, are done—by this mighty power. It would almost seem that the mechanical resources of the world have been exhausted, and that steam, like the conqueror of old, asks for new worlds to conquer. And as with the steam engine, so is it with other combinations of mechanism, for the engineer has scarcely left a province of the vast realm of science and art uninvaded. Yet men have by no means reached the limit of their mechanical progress, for there are yet many weighty problems to be solved; much of what is done has to be simplified and improved; much that is hoped for remains to be realised, and perhaps much that the human mind has not yet conceived, remains to be carried out. It is still for the engineer—and more, perhaps than ever it was—to know, to think, and to dare, for it is only by full and accurate knowledge, by careful and patient thought, and by that happy boldness which laughs at obstacles, that Nature and her powers can be yoked to the car of triumphant humanity.”

88. *System a Means of Economy.*—“Those who have been connected with the business of large manufacturing establishments, or have assisted in the management of corporations where employes were numbered by hundreds and their expenses have counted by hundreds of thousands yearly, readily recognise and value the observation of a rigid and minute system of attention to detail and care for the ‘little things.’ A carelessness in one

single matter, affecting the use and waste of the most insignificant article employed by these concerns, would seriously affect the annual balance sheet.

“What is important to these cannot be unimportant to the smaller fry, whose limited profits are made by a close calculation of the coppers. The small mechanic who employs from three to thirty hands is seriously interested in the matter of saving in little things. It is painful sometimes to visit a small shop and note the waste and extravagance, the want of careful foresight and judicious economy, which is robbing the proprietor, year by year, of that which his labour and enterprise has fairly earned. A machinist will have in use oilers which pass a stream sufficient to lubricate the journals of a marine engine; or he will, for the want of adjusting a pulley or lining a shaft, cut and wear a belt worth ten or twenty dollars, or destroy a set of boxes. The scrap iron is swept up and thrown upon the dust heap; long bolts fitted with nuts are cut in two, instead of forging one for the purpose required. The grindstone is gouged and scored for want of a little care, necessitating its razing once a-week or once a-month when it should have been kept in order for six months. We might go on and enumerate many more of these senseless and careless leaks, which, in the aggregate, make a fearful raid on the proprietor's pocket, but we will mention only one other, not so apparent, though hardly less serious.

“Want of order loses shop owners a great many dollars annually. The old saw, ‘a place for everything and everything in its place,’ is not improved by having ‘a good many places for everything.’ Some workmen have the bad habit of leaving a tool where they last used it, and a lazy habit of forgetting all about it. Such men will cost half their wages to their employers. A job which, if the implement required was at hand, would occupy only thirty minutes, requires an hour, counting the time spent in looking for the tool, and that spent in putting it into shape for use; for it often happens that tools thus left everywhere are not taken care of in other respects. In every well-ordered shop, in every one which is run for profit, there should be an unvarying rule that every tool or implement should be returned to its place as soon as done with. If it is one in frequent or general use, the last user should be compelled to see

that it be left in good shape for the next man. As the military books say, 'this rule is general,' and no exception should be made to it. Racks for drills, shelves for taps, drawers for files and chisels, location for hammers, are found in every shop; but often the drills are stubs without points, the taps are broken or clogged with 'gurry,' the files are worn out or broken, the chisels cracked, etc. But if these matters are tolerably well attended to, others may be neglected. There should be a box to receive all old bolts, screws and nuts; they are 'handy to have in the shop.' Another for cast-iron scraps, another for pieces of wrought iron, saving the forger often from cutting a bar; another for old brass and copper, and one for steel scraps.

"These little things are well worthy the attention of the foreman and the employer. No good workman will object to stringent rules in this respect. He knows it is of immediate advantage to him in saving annoyance and profanity, and is of future advantage by giving him a habit of order affecting his whole life. No employer who has introduced and honestly tested this system of economy and order could be induced to lapse into old habits of easy-going heedlessness."—*Scientific American*.

89. *The Duty of Recording Experiments*.—"Most experiments in science and art are made with a view of substantiating some particular theory, or of elucidating some supposed fact, and if they fail to do this they are often looked upon as unsuccessful and valueless, and no record is made of what the investigator would consider his failure.

"The idea is a wrong one. Every experiment is a success. If it did not result as was desired, it is no less a success than if it answered the most sanguine expectations of the projector. To prove that a thing cannot be done, or that a theory is false, may be as valuable as to achieve success, or establish a proposition. If not of direct advantage to him who made the test, it might be invaluable to others. Therefore, it is a duty the scientific man and practical mechanic owes to his kind, to keep a careful record of every manipulation, and trial with new combination.

"A few days ago an eminent mechanic, in speaking of some investigations he had made in regard to the expansive force of steam, said that he called on a firm who had followed the path of investigation for sixteen years, and ascertained that because the

experiments had not determined the facts they sought to establish, they had preserved no record of them, or, if they made such records they had destroyed them. In this case an injustice had been done to other inquirers into the same subject.

"The data, the processes, and the results of experiments, from their incipency to their completion, ought to be carefully noted, and whatever may serve to throw light on the causes of failure, or serve as a means of furthering additional investigations, should be recorded and preserved.

"In every thing which is of use to man, the grand present result is the fruit of the work of generations. It can hardly be estimated how much further we might have advanced if the duty of recording means, object, and result had always been recognized. He who tries a new experiment adds directly to the world's wealth of useful knowledge. That the result did not answer his expectations argues nothing against this proposition. Many of our most valuable discoveries have come from these negative investigations. To prove that an object sought is opposed to the laws of nature and the qualities of matter, may be of as much benefit as to ascertain the converse.

"Every experimentalist should bring to his investigations an honest desire to ascertain the truth, even if it proves him to be in the wrong. But many make tests simply to establish and demonstrate a favourite proposition, and, if not successful, carefully destroy all record of what they consider their failure. This is not wise from any point of view. The vocation of our practical men is higher than that of merely distinguishing or benefiting themselves. They work for the world at large, and if by a fortunate discovery or useful invention they make themselves rich, the world receives a larger share of the benefits than they. The inventor of the sowing machine, or those portions which make it a necessity, has been made immensely rich, but his fortune is but dust in the balance when compared with the benefit his inventions have conferred on the world.

"It is a rule without an exception, that no man can absorb to himself the full benefit of an invention. He must share it with the mass, and when he selfishly attempts to hide his repeated failures by the light of his one grand success, he does violence to his own conscience and injustice to his fellow-men."—*Scientific American*.

REFERENCE TO OTHER PAPERS AND ARTICLES CONNECTED WITH DIVISION TWELFTH, FOR WHICH THERE IS NOT SPACE IN PRESENT VOLUME.

(All the dates refer to the year 1866.)

Note.—We classify the papers and articles referred to in this Division, under two heads. (a) *Ordnance.* (b) *General.*

(a) *Ordnance.*

- Rifling and Calibre*,—Mech. Mag. Aug. 31.
The Non-Recoil Gun,—Engineering, April 27.
The Blakeley Gun,—Engineering, Jan. 12.
Repeating Rifles,—Mech. Mag. May 11.
Breech-Loading Rifles,—Mech. Mag., May 20 and 27.
On the New System of Manufacturing Guns at Woolwich,—Engineer, June 22.
The Non-Recoil Gun,—Engineering, March 30, Illus.
Heavy Ordnance,—Engineering, July 13.
The Prussian Needle Gun,—Mech. Mag., July 13.
Cochran's Breech-Loading Rifle,—Mech. Mag., July 27, Illus.
Congreve Rockets,—Mech. Mag., Aug. 31.
British Armour,—Mech. Mag., April 6.
British Armour,—Mech. Mag., Nov. 30.
Major Palliser's Projectiles at Shoeburyness,—Engineer, Sep. 28.
Breech-Loading Rifles,—Mech. Mag., Aug. 3.
Modern Armaments,—Engineer, July 27.
The Story of the Zundnadel Gun,—Engineer, July 27.
The Palisser Bolt,—Mech. Mag., Aug. 10.
Rifled Ordnance. The Woolwich and Lancaster Systems,—Mech. Mag., June 12.
Iron-Plated Fortifications,—Mech. Mag., Oct. 12.
Repeating Rifles,—Mech. Mag., Oct. 12.
Chilled Shot,—Mech. Mag., Sep. 7.
Military Breech-Loaders—The Needle Gun,—Engineer, July 13.
Iron Forts,—Engineer, Jan. 5.
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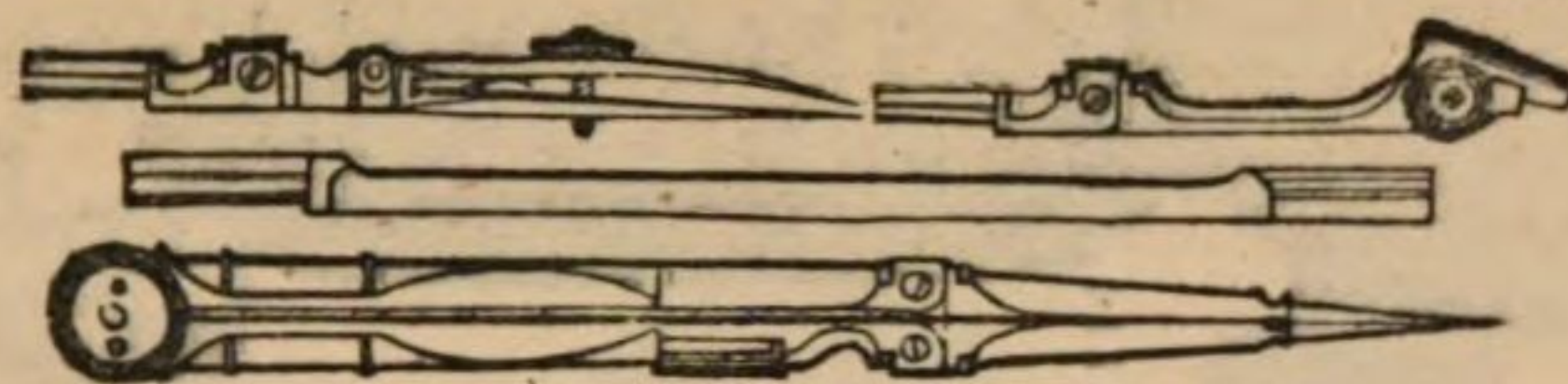
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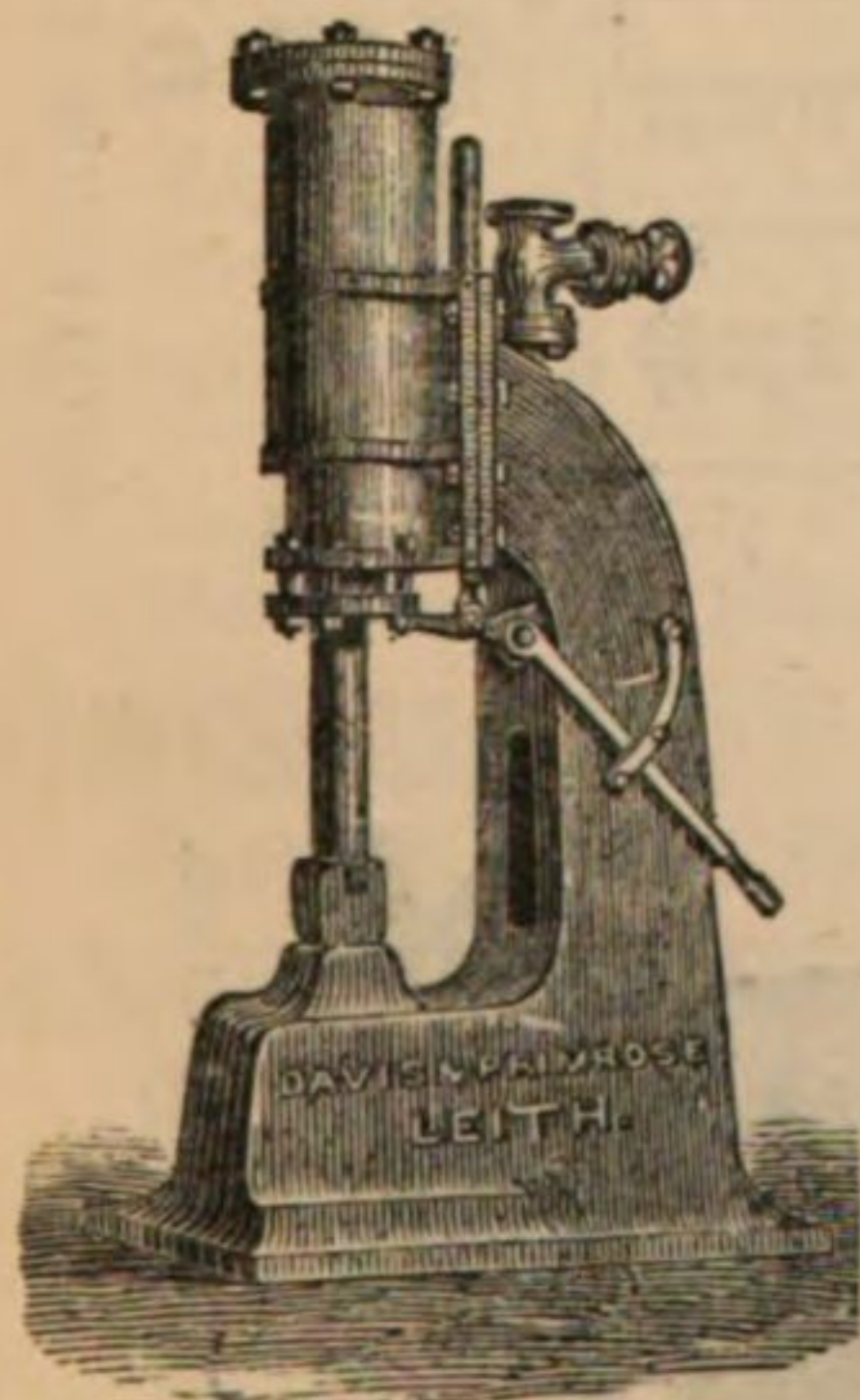
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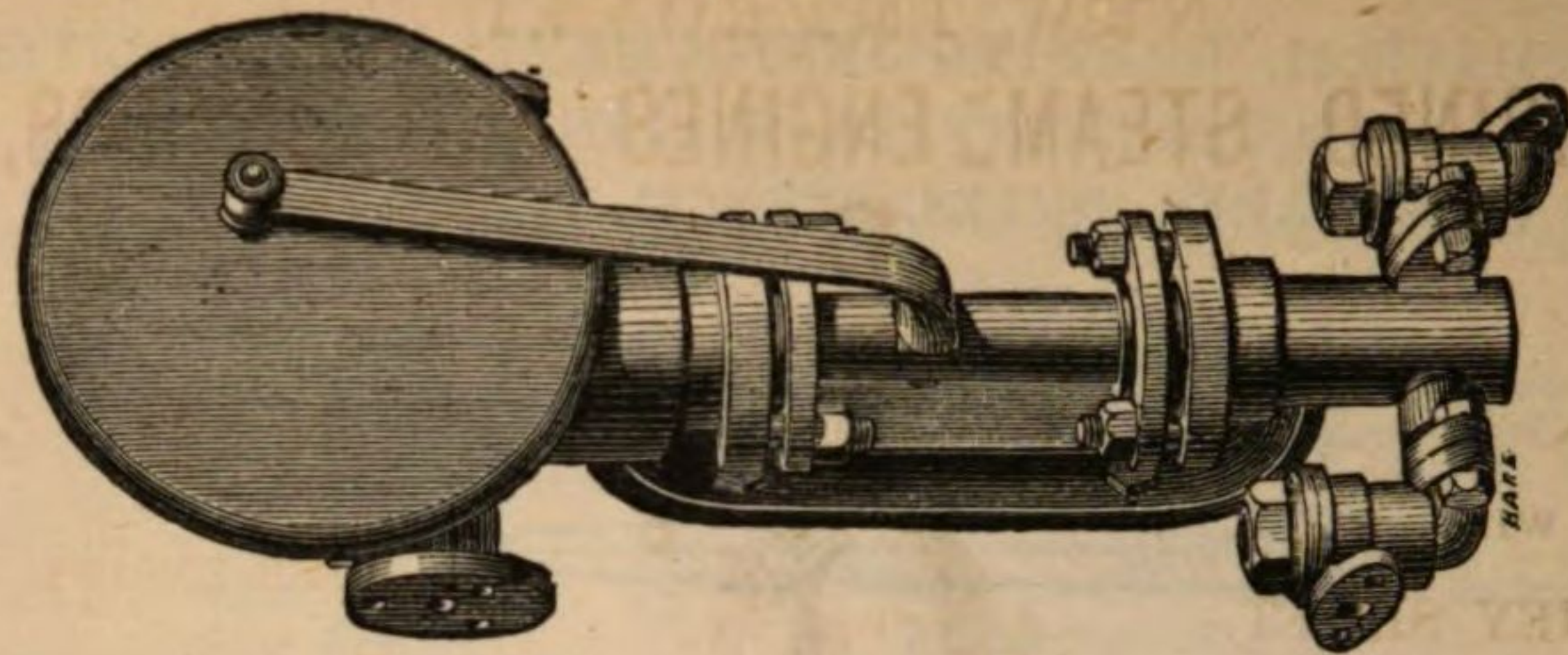
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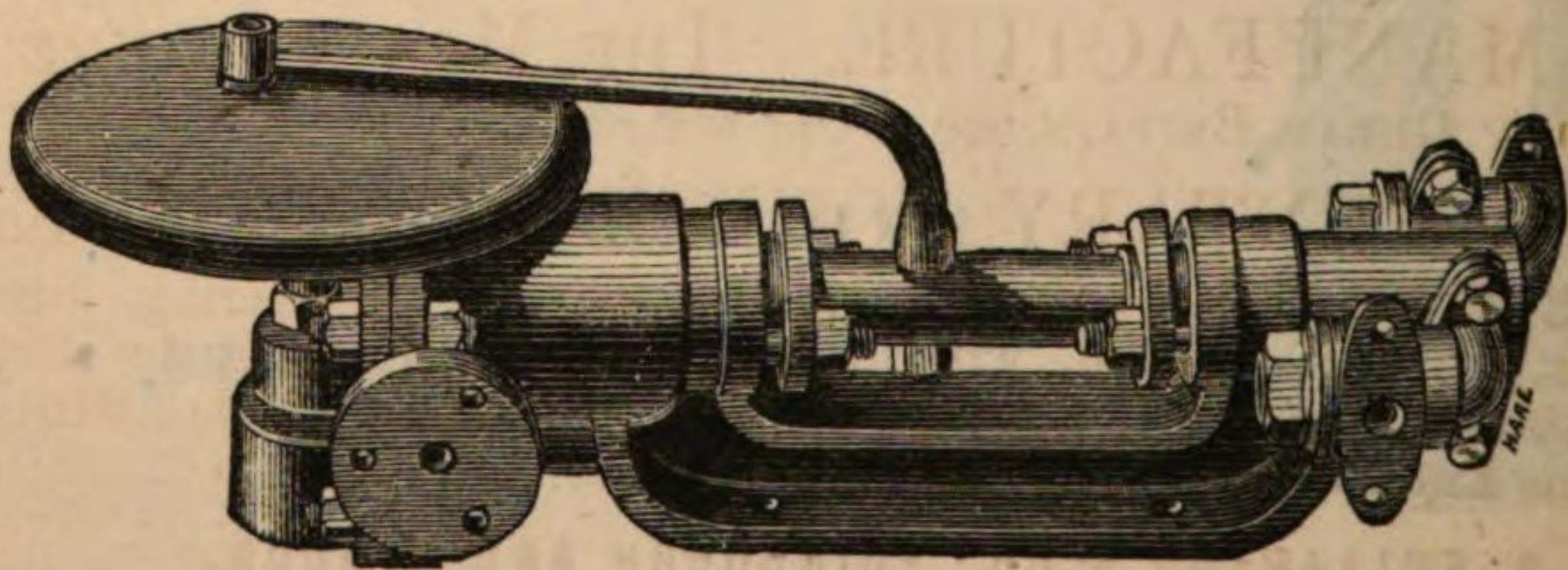
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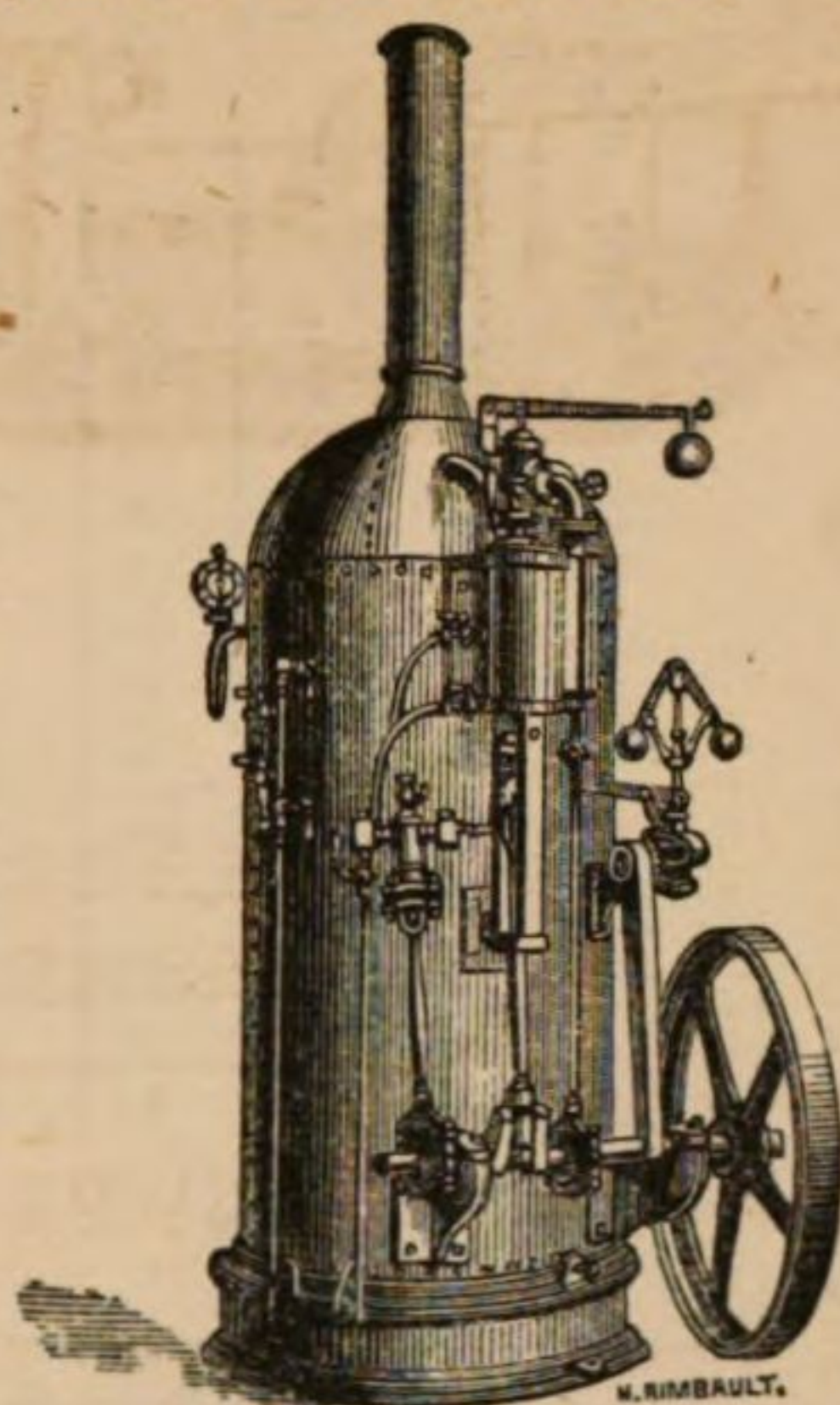
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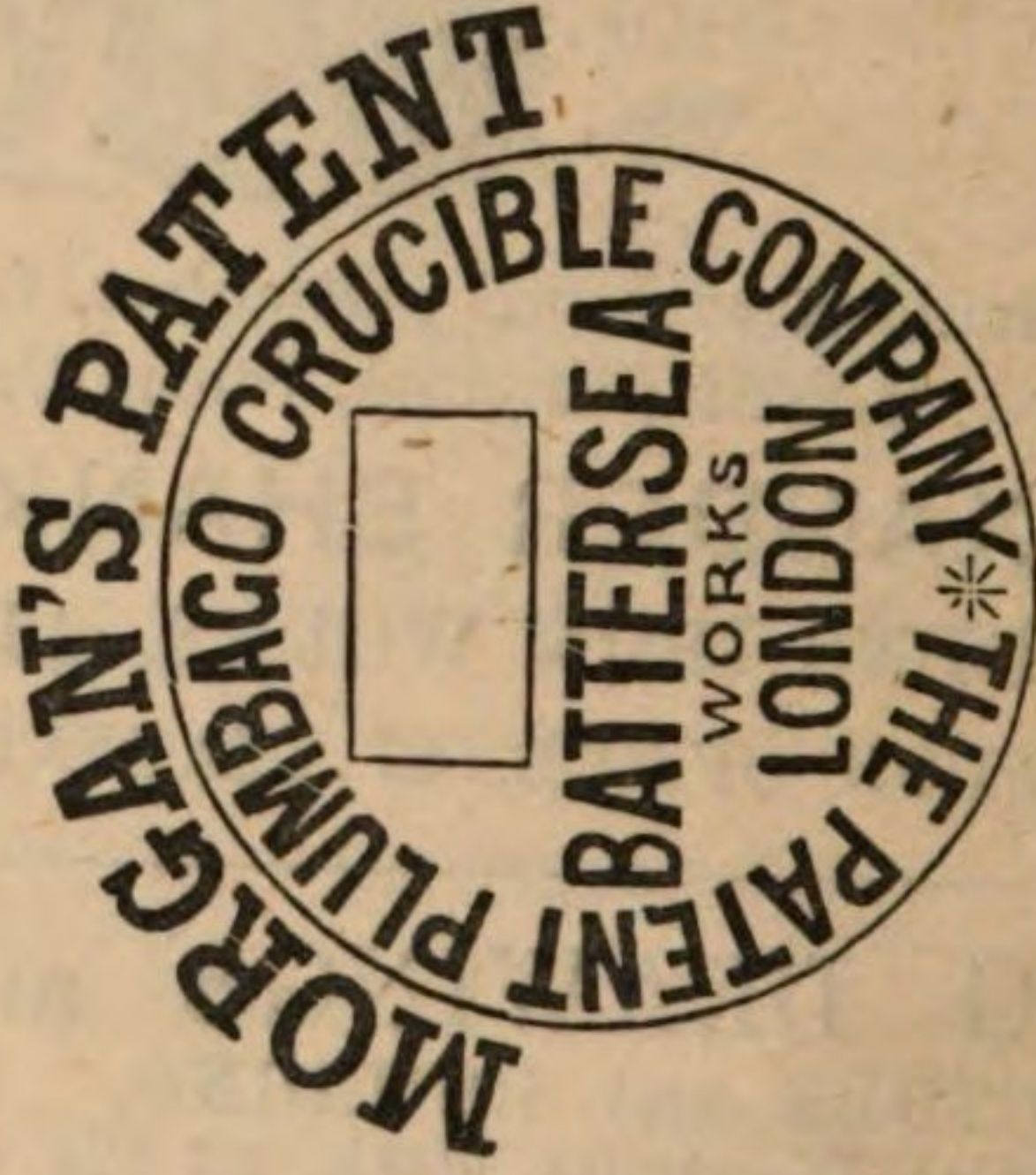
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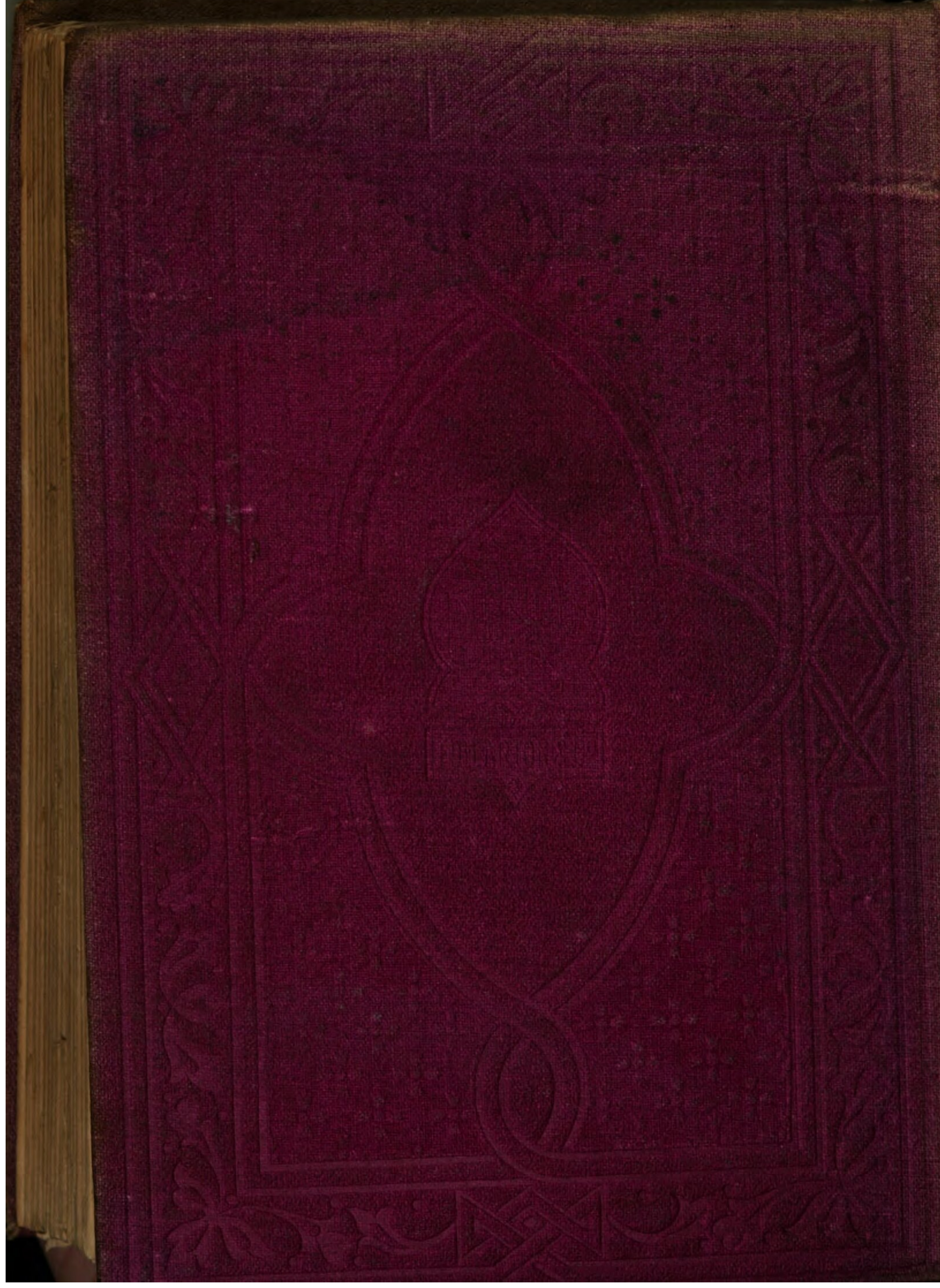
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